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products by aquatic and land animals and plants in connection with the tests in the Pacific last fall. Information will be obtained on the distribution of fission products in waters of the test area; their accumulation by fish, clams, corals, and microscopic plants and animals; and the presence of radioactive material at the bottom of the ocean.

### Atomic Bomb Casualty Commission

Medical studies of the delayed radiation effects on the populations of Hiroshima and Nagasaki are being continued for the Commission by the Atomic Bomb Casualty Commission. Inhabitants of the two cities, as well as their progeny, are given periodical medical examinations. Examinations are also given newborn babies whether or not the parents were within the 2,000 meter range of the explosions. Any consistent differences between those who were within the area and those outside may be expected to have been caused by the radiation. Five-year summaries on this work are now being tabulated and will determine the nature of the investigations for the years ahead. An increasing participation by Japanese medical and scientific personnel is expected.

The studies completed to date indicate slight but definite effects due to radiation. However, it is recognized that several more years of continuing clinical investigations and analytical determinations are required before firm conclusions can be established. In addition to the medical aspects of the problem, data are being accumulated which suggest that the severity of the radiation injury was correlated with the distance from the explosion, and therefore with the radiation dosage. Where differences from this rule are found, it appears that the subjects were partly shielded, and so it may be possible to evaluate the effectiveness of the different degrees of shielding experienced by people—for example, those who were in open areas, wooden houses, or concrete buildings.

During the studies, it was discovered that several Japanese inhabitants of Hiroshima went to Nagasaki immediately after the bombing and were exposed not only to the first but to the second bomb. These people are under study, but the effects of this double exposure have not yet been evaluated.

### Radiation Instruments Development

The need for instruments to detect and measure radiation has grown rapidly with the increasing activity in the atomic energy field and the

# PUBLIC SAFETY IN CONTINENTAL WEAPONS TESTS

Twenty nuclear devices or weapons have been exploded since early 1951 at the United States Atomic Energy Commission's Nevada Proving Ground, a 640-square-mile tract of desert land 65 miles northwest of Las Vegas, Nev. These explosions have been tests, conducted for the purpose of developing new and improved atomic weapons and determining the effects of atomic detonations.

In large part, the energy released in these detonations has expended itself upon the barren ground of the test area and the instruments, pieces of equipment and structures placed there for experimental purposes. However, it is impossible to confine the effects of the explosions entirely to the proving ground. Blast waves have caused minor damage as far away as Las Vegas. Radioactive particles in the cloud following a detonation may fall back to earth virtually anywhere within the United States. The brilliant flash of light accompanying a detonation is potentially a source of hazard to persons as far as 30 miles away.

For these reasons, the public has a direct interest in the precautions taken by the United States Atomic Energy Commission to prevent damage to the public health and safety from continental test detonations.

"Fall-out"—the name given to the descent back to earth of the radioactive particles in the cloud following an explosion—already has caused a degree of public concern in some communities. The increase in natural radiation caused by fall-out may be measured on the sensitive instruments used for radiation detection. Improper use of these instruments, or faulty interpretation of their readings, can result in an inaccurate report that residents of a community are being exposed to dangerous levels of radioactivity. In addition, many persons, not realizing that they are continuously exposed to radiation from natural sources, may become alarmed by reports of any level of fall-out radioactivity, no matter how small.

This report will explain the precautions taken against hazard to the public from blast or fall-out. It will describe the Nation-wide system of monitoring fall-out radioactivity, and it will assess the possible effect of recorded fall-out levels upon the public health.

The Commission's Division of Biology and Medicine is responsible for the coordination and evaluation of data resulting from monitoring



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and research activities relating to fall-out. This evaluation forms the basis for the establishment of policies to insure the protection of the public.

*Effects of Weapons Tests*

The following general statements may be made concerning the effect of the 20 nuclear detonations held within the continental United States to date:

(*a*) No person has been exposed to a harmful amount of radiation from fall-out. In general, radioactivity resulting from fall-out has been many times below levels which could cause any injury to human beings, animals, or crops. The highest level of fall-out radioactivity detected as a result of any of the detonations—recorded at a mine a few miles from the boundary of the Proving Ground—was within the safety limits recommended by an advisory committee formed to study the radiation hazard involved in test detonations.

(*b*) Successive tests have not resulted in the accumulation of a hazardous amount of radioactivity in the soil. Uptake of radioactive material in the soil by plants has not created dangerous levels of radioactivity in food.

(*c*) Fall-out radioactivity is far below the level which could cause a detectable increase in mutations, or inheritable variations.

(*d*) No person has been injured by blast waves, although blast has cracked plaster and broken windows in communities near the proving ground.

The United States Atomic Energy Commission decided to hold nuclear test detonations within the boundaries of the United States only after the most careful evaluation of potential hazards, both by Commission scientists and others acting in an advisory capacity. Experience to date has borne out their conclusion that nuclear tests can be held at the Nevada Proving Ground without serious hazard to persons, animals, crops, property, or industry.

## Establishment of the Nevada Proving Ground

The Nevada Proving Ground has proved to be of great value in the Commission's program for developing improved atomic weapons. Test detonations are an essential part of this development program, and tests in this country have several advantages over ones held overseas. Continental tests have been less expensive than ones in the

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Pacific. At least as important as this saving of public funds has been the shortening of the period which elapses between development of a device and incorporation of the test results into weapons designs. The Nevada tests have greatly increased the rate of acquisition of knowledge of weapon design and weapon effects, and thus have materially strengthened the national security.

The following section will describe in further detail the need for testing nuclear devices, the decision to establish the Nevada Proving Ground, and the advantages resulting from continental tests.

## The Need for Nuclear Test Detonations

The United States Atomic Energy Commission has conducted six series of test atomic explosions. Three series have been held at Eniwetok (spring 1948, spring 1951, and fall 1952), and three at the Nevada Proving Ground (January–February 1951, October–November 1951, and April–May–June 1952). Each of the tests involved a major expenditure of money, manpower, scientific effort, and time. Nevertheless, in accelerating the rate of weapons development, they have saved far more than their cost. They have proved to be of great importance in fulfilling the Commission's responsibility for developing, manufacturing, and storing a stock of efficient and militarily useful atomic weapons to meet the needs of the military services.

It is possible to evaluate many weapons principles and designs in the laboratory or by mathematical computation. However, under certain circumstances, the only practical method of evaluation is that of actually detonating a nuclear "gadget," or device, to test the design or principle involved. Often the device to be tested is not itself a useful weapons design. However, the information obtained from the test may be utilized in improving the design of stockpile weapons.

There are other motivations for field tests. A final version of a device may be proved-in, or a fundamental problem in weapon technology may be explored. Tests may give the Department of Defense information regarding the effects of a weapon under certain conditions, or may answer questions of concern to the Federal Civil Defense Administration or other agencies. Most field tests are primarily developmental in nature, but their costs in material and effort is so great that each test is designed and used to answer as many questions as possible.

## The Decision To Establish a Continental Test Site

The world's first nuclear explosion—the test detonation near Alamogordo, N. Mex., in July 1945—occurred within the continental limits

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of the United States. The next test nuclear detonation within the United States occurred nearly 6 years later, on January 27, 1951.

Between these two dates, the United States exploded seven nuclear weapons or devices overseas. Two weapons were detonated over Hiroshima and Nagasaki in 1945 for military purposes, two test detonations were held at Bikini Atoll in mid-1946, and three test detonations were held at Eniwetok in the spring of 1948.

The Bikini detonations were conducted primarily to answer military questions as to the effects of overwater and underwater bursts, and there was no possibility of their being held in this country. When the need for further tests became apparent in late 1947, however, scientists proposed that they be conducted in the United States.

The advantages of continental testing were obvious. The Bikini tests had demonstrated the cost of an overseas operation in money, time, and manpower. Continental testing would not involve the heavy expense of transporting and maintaining thousands of persons overseas. Even more important was the saving of time and scientific effort which continental tests would make possible. Scientists could return to their laboratories between detonations, instead of interrupting their other work to spend months overseas.

### *Possible Hazard From Fall-Out*

These factors weighed heavily in favor of the establishment of a continental test site. On the other side of the balance, however, was the question of whether the blast or the radioactive fall-out from test explosions might injure persons or damage property off the site.

The Alamogordo test had demonstrated the possibility of hazard from fall-out. Cattle near the test site suffered skin burns and subsequent graying of hair on their backs as a result of radioactive fall-out from this detonation.[1] Water containing fall-out particles was used in the manufacture of strawboard, which later was used to package photographic film. As film is extremely sensitive to radiation, a quantity of it was fogged by the contaminated paper.

A rapid survey of possible locations for a continental proving ground was made in 1947, but the Commission felt that tests should be held overseas until it could be established more definitely that continental detonations would not endanger the public health and safety. The 1948 test series, the first since the creation of the Atomic Energy Commission, was held at Eniwetok Atoll in the Pacific.

[1] These cattle have been under observation since shortly after their exposure. There has been no detectable damage to their health or reproductive ability as a result of the radiation they received.

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### *Increasing Need for Continental Site*

The need for a "backyard" test site became increasingly apparent during late 1949 and 1950. The pace of weapons development had been stepped up, and it become clear that the program would require more frequent tests than could be conducted feasibly in the Pacific. The rate of development of new and improved nuclear weapons depended on whether or not a continental site could be utilized.

Available locations were surveyed again, and the Nevada site, then a portion of an Air Force bombing and gunnery range, was selected as the most feasible one. This site had several advantages. One was that it is only 3 hours distant by air from the Los Alamos Scientific Laboratory, at Los Alamos, N. Mex., and the Sandia Laboratory, at Albuquerque, N. Mex.—both key points in the nuclear weapons development program. In addition, the location and relative isolation of the Nevada site provided safety factors in relation to blast and fall-out, particularly because the prevailing winds blow from the test site for many miles across a relatively unpopulated region.

Careful review of all available research and test data relating to fall-out indicated that, under the controls planned, there was adequate assurance of public safety. The decision to establish a continental test site was made late in 1950, and the Nevada Proving Ground was first used in January 1951.

### *Pacific Proving Ground*

Since the larger test detonations could not be held within the United States with the requisite degree of safety, construction of firing areas and supporting facilities at the Pacific Proving Ground at Eniwetok proceeded, and tests were held there in the spring of 1951 and the fall of 1952.

## Value of the Nevada Proving Ground

Three test series in Nevada during 1951 and 1952 have demonstrated that the continental test site is even more valuable to the nuclear weapons program than had been anticipated. The Los Alamos and Sandia Laboratories' backyard workshop in Nevada has permitted tests to be set up quickly and conducted frequently, and has resulted in major savings of time, manpower, and money.

These savings become obvious in a comparison of the cost and effort involved in the three test series in Nevada during 1951 and 1952 and in the two test series at Eniwetok during the same years. Each of the Eniwetok series involved all of the transportation, sup-

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ply, and technical problems created by a continental test series, multiplied many times by the distance to the overseas location. Work on the spring 1951 series, for example, began in 1950, and approximately 9,000 military, civilian contractor, and Commission personnel were tied up for many months.

The Nevada tests have been much less costly in manpower and time. The spring 1952 series in Nevada, for example, required the services of fewer than 2,500 individuals, including construction workers. Scientists and technicians were able to participate in a test on one day and return to their laboratories on the next. As a result, it was possible to evaluate the data from one detonation in time for the results to affect the next test. Fully evaluated results were incorporated into the development and manufacturing program much more rapidly than has been possible with overseas tests. There is no question that the Nevada Proving Ground has materially cut the time lag between the scientific projection of a new weapon or weapons principle and its entry into the weapons program.

Savings in manpower and time obviously result in saving of public funds. Continental tests have proved to be much less costly than overseas operations. When total costs are related to the number of detonations, the savings are even more impressive.

The Nevada Proving Ground also has made it possible for military field units to participate more fully in developmental and effects tests. A new value has been the use of test detonations by the services to conduct simulated combat maneuvers, to indoctrinate thousands of personnel in the effects of atomic explosions, to orient staff and instructional personnel, and to study various tactical implications.

### *Value to Civil Defense*

The Nevada Proving Ground has been of value to civil defense officials, both at national and at State and local levels. Through cooperation with the Federal Civil Defense Administration, it has been possible for civil defense personnel from FCDA and State and local organizations to participate in weapons tests in such capacities as radiological safety monitors or as technical observers. Use of the Nevada Proving Ground also provides opportunity to study the effects of an atomic detonation on civil structures and equipment. Public understanding of radiation hazards has been improved by the continental test program. At least one State civil defense organization has collected and analyzed fall-out particles as a practice operation in radiological defense.

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*Operating Controls*

Operating controls to prevent hazard to the public have been successful. There has been no instance of harmful exposure of human beings to radiation from fall-out, and only a single reported instance of observable radiation effects on cattle (grazing immediately adjacent to a firing area). While blast has broken windows and cracked plaster as far away as Las Vegas, it has not injured anyone. Information obtained on the propagation of blast waves under various atmospheric conditions now makes it possible for the test organization to select detonation times which will reduce the possibility of blast damage to surrounding communities.

## Effects of Weapons Tests

A nuclear detonation releases tremendous energy, equivalent in a so-called "nominal" burst to approximately 20,000 tons of TNT.[2] However, the impressive energy released in nuclear detonations is dwarfed by the energies involved in natural forces. For example, a strong earthquake involves about as much energy as would be released by a million nominal atomic bombs. About 1,000 nominal bombs would be required to match the kinetic energy of a moderate hurricane.

While nuclear explosions have not changed the weather nor caused tidal waves or earthquakes, the forces they release are exceedingly powerful within a limited area surrounding the point of detonation. The area of effective destruction varies with the amount of energy released by the nuclear device. Under the operating controls used in Nevada, thousands of military personnel have occupied fox holes 7,000 yards distant from detonations without casualty. Other participants and observers, with no protection other than goggles, have witnessed tests from a distance of 10 miles without injury.

### Characteristics of a Nuclear Detonation

An atomic explosion releases energy as heat, light, and nuclear radiation. The heat energy, which is released instantaneously, produces very hot gases at a high pressure, and the outward movement of these gases creates a shock wave, which is capable of severe destructive effects.

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[2] This was approximately the energy release of the atomic bombs exploded over Hiroshima and Nagasaki. In discussing the effects of atomic deonations, this report will have reference to those of "nominal" energy yield.

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A portion of the nuclear radiation is released at the time of detonation as each reacting atomic nucleus fissions, or splits into two parts. The remainder is emitted by these parts, called fission products, over a period of time. These radioactive fission products are components of the cloud which follows a nuclear detonation.

The phenomena following the aerial detonation of a nuclear device of nominal yield may be summarized as follows:[3]

Within a few thousandths of a second after a detonation, the heat, light, and instantaneous nuclear radiations sweep the target area, and a luminous sphere or "fireball" appears as the air is heated to incandescence by temperatures approaching a million degrees centigrade. At the end of 1 second, the fireball reaches its maximum radius of 450 feet and begins to rise like a gas balloon, and the shock front of the air blast is visible 600 feet ahead of the fireball.

### *Formation of the Cloud*

By the end of 10 seconds, the intense luminosity of the fireball has almost died out, the shock wave has traveled 12,000 feet and passed the region of maximum damage, and formation of the cloud has begun. The immediate effects of the explosion have run their course, leaving only the delayed effects of residual radiation and the possibility of more distant air blast effects. The cloud, containing sucked-up dirt and debris, and radioactive oxides of fission products, rises high into the air. The base of the cloud's stem settles back onto the firing area, while the cloud itself is carried downwind. It may remain visible as a cloud for an hour or more before dissipating into an invisible mass of air and particles of debris.

### *Range of Effects*

Neither heat nor the nuclear radiation released at the moment of the detonation is hazardous outside of the limits of the proving ground. Beyond about 7,000 feet, the nuclear radiation is virtually harmless. The heat resulting from a detonation will burn skin seriously and will ignite combustible materials 2 miles from the target area, but is noticeable only as a wave of warmth at a distance of 10 miles.

[3] A more detailed and technical description of a detonation and of its physical effects is contained in "The Effects of Atomic Weapons," prepared under the direction of the Los Alamos Scientific Laboratory for and in cooperation with the U. S. Department of Defense and the U. S. Atomic Energy Commission (see Appendix 8).

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The other three effects of an atomic explosion—light, blast waves, and residual radioactivity in the cloud—can present a safety hazard outside of the proving ground under certain conditions. These effects will be discussed below.

## Light Effects

Viewed at a distance of about 6 miles, the brilliant flash of light from a nominal detonation is 100 times brighter than the sun. Flashes from Nevada tests have been brightly visible in broad daylight in Las Vegas, 80 miles away, and one was reportedly seen as far away as Kalispell, Mont.

The hazard from flash is confined to the test site and the immediately adjacent region up to 30 miles from the target area. The brilliant light could temporarily blind or confuse motorists or airplane pilots in this area. In addition, exposure of the unprotected eye at too close proximity would result in a blind spot which might be permanent. The danger decreases with distance from the detonation, but is greater during predawn shots, when observers' eyes are adjusted to night vision.

Various precautions are taken to protect site personnel and the public from flash. Observers and workers at the test site either turn their backs before a detonation or wear special high-density goggles. Observers off the site are warned not to look toward the proving ground during periods when tests are anticipated unless they are wearing sun glasses.

Cautions are issued against the use of binoculars at any point within the site region. Nonofficial air traffic over the site is prohibited, and warnings against flight in the region are issued to pilots through the Civil Aeronautics Authority. Roadblocks have been maintained on occasion to prevent hazard to motorists, but the usual precaution is the general warning of an imminent operation which is issued in the site region.

## Air Blast Effects

The air shock wave produced by an aerial nuclear detonation of nominal yield is the most important agent in producing destruction. Most of the blast damage from an explosion of this size occurs within a radius of 12,000 feet during the first 10 seconds after the detonation. By 30 seconds, at a distance of about 7 miles, almost all of its immediate energy has been dissipated and only light damage, such as to plaster and windows, results. At a distance of 7 or 8 miles an

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observer may feel a jolt or a strong push from the air blast, accompanied by one or more sharp slaps of sound.

Outside the definable area of immediate effect, air blast may behave erratically because of meteorological conditions. Blast waves which have bounced over observers only 10 miles from ground zero, creating little noise or shock, have broken windows and cracked plaster 80 miles away in Las Vegas. The blast waves from one detonation were registered on equipment and distinctly heard more than 600 miles away in Albuquerque, N. Mex.

### *Effect of Weather*

The intensity of blast waves at any locality depends more upon various weather phenomena than upon the energy yield of the detonation. At the instant of detonation, blast waves start out in all directions. Those which strike the ground are reflected into the air. In traveling through air, sound waves are affected by two weather factors—temperature and wind. Under ideal atmospheric conditions for a test, there would be no winds and air temperature would decrease with height above earth. Since blast waves travel more slowly in cool air than in warm air, under such conditions all blast waves would bend upward.

Above desert land, however, the air sometimes is warmer at an altitude of 1,000 to 2,000 feet than it is at the earth's surface, creating a "temperature inversion." The warmer layer of air bends the blast waves back down to earth, from which they bounce again. Each time they strike the earth they create a zone of noise, losing energy with each reflection. The heavy focus of energy occurring at the inner limit of each noise zone is known as a "focal point."

Wind accounts for the fact that shock waves in one direction from an atomic explosion may be stronger than those in the opposite direction. Wind can aid or deter the atmospheric temperature pattern in the formation of blast foci.

### *The Troposphere*

The troposphere is the name which meteorologists apply to the bottom 6 miles of the earth's atmosphere. It was the temperature inversion in this layer that bent back damaging blast waves from the explosions of February 2 and 6, and again on November 1, 1951. At the time of the November 1 detonation, a double focus was created at Las Vegas. The blast rays starting in the northwest direction were

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all bent upward, overpassing Goldfield, 80 miles away. But in the opposite direction, toward Indian Springs, Boulder City, and Las Vegas on the southeast, two focal points occurred, one at 6.6 miles and one at 40 miles. After one reflection of the focus at 40 miles, and 11 reflections of the focus at 6.6 miles, the blast waves reached Las Vegas in sufficient strength to break 11 plate glass store windows and knock dishes off the shelves of a resort hotel storehouse.

### *The Ozonosphere*

Another, higher atmospheric layer also affects blast—the ozonosphere, extending from 25 to 40 miles above the earth. It bends back to earth some of the blast waves which escape through the troposphere. The focal points it creates are farther apart, varying from 60 miles in winter to 120 miles in summer. Several communities in Nevada and Utah have received small shocks from the first return to earth of waves reflected by the ozonosphere. Subsequent ozonosphere reflections of the shock waves have been felt or heard by residents in Arizona, California, and New Mexico.

### *The Ionosphere*

Still another high atmospheric layer called the ionosphere extends farther upward from an altitude of 50 miles. Focal points created by the ionosphere may be much further apart than those created by lower atmospheric layers. No damage has been reported from ionosphere shocks, although blast waves have been recorded at St. George, Utah.

### *Settlement of Claims*

The Commission anticipated that Nevada tests might produce minor blast damage outside the exclusion area. By contract with the General Adjustment Bureau, it provided for the prompt local recording and investigation of claims. The Bureau's investigation is supplemented by those of engineers, architects, and other experts in construction in the community from which the claim originates. The investigation is extensive enough to determine whether or not the damage actually resulted from the test, and in a considerable number of cases it has shown that damage was solely or materially due to aging or to construction. The Tort Claims Act enables the Commission to make

prompt settlements of justifiable claims which do not exceed $1,000. No claims for blast damage have exceeded that figure.[4]

## *Meteorological Studies*

Prior to the second test series (October–November 1951), the Commission established in August 1951 a study of the effects of meteorological conditions on blast phenomena to make possible the prediction of where the blast would strike and the resulting shock strength.

The extensive weather service net centering at the proving ground was utilized to record pre-shot conditions, and to forecast and subsequently record detonation-time conditions.

Manned microbarographic recording stations were set up in eight communities surrounding the proving ground at distances of from 25 to 135 miles (seven in Nevada, one in Utah). Beginning in August, a number of high explosive charges was fired and shock levels were recorded. During the October–November 1951 test series, a charge of high explosive was fired one hour prior to each nuclear detonation, permitting a blast pressure report to be received from each recording station before the nuclear detonation finally was ordered. The data obtained from the high explosive detonations were utilized to make predictions of wave patterns from the nuclear detonation.

## *Blast Wave Predictions*

A fair degree of accuracy was attained in predicting the pattern of blast waves, with the accuracy depending primarily on whether the forecast of weather conditions was accurate. Variations in meteorological conditions between the time of the high explosive shot and the nuclear detonation were found to affect the pattern materially.

The program was continued through the spring 1952 test series, and the timing of several detonations was changed because of meteorological predictions. Officials of the test organization believe that the blast predictions have provided good indications of possible blast and shock patterns and have helped to avoid damage from air shock. However, the many variables still cannot be fully anticipated, and there is no certainty that property damage always can be avoided.

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[4] The initial continental series in January–February 1951 resulted in 132 claims, with settlements totaling $15,000 allowed on 113. Eighteen were for major window breakage, principally plate glass windows in downtown Las Vegas resulting from the February 2 and 6 shots, and 95 were primarily for cracked plaster inside or cracked stucco outside, but also included minor window breakage. A total of 294 claims resulted from the second series (October–November 1951), of which 268 were settled for a total of $27,929.59. All resulted from the November 1 blast. Ten allowed claims were again for plate glass windows in Las Vegas, the balance being for cracked stucco, plaster, and smaller windows. Twenty-seven claims resulted from the spring 1952 series, all for cracked plaster and including claims from Modesto and Sacramento, Calif. All were disallowed. For the 3 series, 453 claims were filed, settlements were reached on 381 or 89 percent and payments totaled $42,929.

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Blast predictions have provided a basis for pre-test warnings to people in specific communities to take such precautions as opening doors and windows and staying away from large glass windows. Warnings have been issued on numerous occasions, and public cooperation has been good. The recordings of blast pressures resulting from detonations have been useful in evaluating damage claims.

### *Blast Damage in Las Vegas*

Although the Nov. 1, 1951, detonation shattered 11 plate glass windows in downtown Las Vegas, the shock wave pressures measured in Las Vegas were very low, only 0.04 pound per square inch. This is equivalent to the pressure of a 40-mile-an-hour wind, considerably less than Las Vegas windows frequently withstand. The damage can be explained by the fact that in air blast a direct compression wave, which would push inward on windows, is followed by a rarefaction wave, which has the opposite effect. Store windows are protected by steel beams on the inside but are held in place only by thin strips of bronze on the outside. All of the windows broken in Las Vegas on November 1, were pushed outward by air pressure inside the buildings when the rarefaction wave struck. The damage might have been prevented if doors or windows had been opened to allow pressure equalization.

## Radiation Effects

It has been noted that part of the nuclear radiation produced by an atomic explosion is released at the moment of the detonation and the remainder is set free in the course of time.

The instantaneous radiation is released in the form of neutrons and gama rays, emitted by each reacting atomic nucleus as it fissions. The residual radiation is emitted by the fission products. These fission products, radioactive forms of a variety of elements, emit radiation at a rate which is inversely related to their half-lives.[5]

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[5] Radioactive atoms release particles or rays from their nuclei in order to reach a more stable energy state. Each emission is spoken of as a disintegration. By definition, half-life is the period of time it takes for half of a given number of radioactive atoms to disintegrate. For example, a quantity of iodine 131 will lose one-half its radioactivity in 8 days, one-half of the remaining activity in the next 8 days, and so on. Iodine 131, therefore, is said to have a half-life of 8 days. Other radioactive elements have longer or shorter half-lives. Following are radiological half-lives of some of the fission products which occur in fall-out.

| Fission Product: | *Half-life* |
|---|---|
| Cesium 137 | 37 years. |
| Strontium 90 | 25 years. |
| Ruthenium 106 | 1 year. |
| Cerium 144 | 275 days. |
| Strontium 89 | 53 days. |
| Barium 140 | 12.8 days. |
| Iodine 131 | 8 days. |

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A downtown Las Vegas window, showing how the glass was sucked out by the rarefaction wave, rather than pushed in by the compression wave resulting from the November 1, 1951, nuclear test at the Nevada Proving Ground.

The fission products and other components of the nuclear device are vaporized by heat and become part of the "fireball" following the detonation. As it rises, the fireball draws up varying amounts of dust from the ground. Some of this dust may have been made radioactive by the neutrons released by the detonation, but most of it is inert. The radioactive fission products condense as they cool, forming part of the cloud originating from the fireball. The large amount of

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initial radioactivity in the cloud decreases rapidly, since many of the fission products have short half-lives. At the end of 1 hour, the radiation emitted is only about five percent of the radiation level 5 minutes after detonation, and at the end of 1 day, the level drops to 0.1 percent. However, some radioactivity remains for many years.[6]

The radioactive particles within the cloud initially are of a wide range of sizes. Particles from less than 1 micron[7] to about 10 microns in diameter are often composed entirely of fission products; larger particles are more likely to consist of fission products condensed on dust sucked up from the ground. Dust particles may be more than 100 microns in diameter.

### *Settling of Dust Particles*

As the radioactive particles begin to descend to earth, they also are carried transversely by wind. The larger particles tend to settle first. Fall-out—the descent of the particles back to earth—may occur in the immediate vicinity of the detonation or as far as several thousand miles away, although it is heaviest near the site. The manner in which the particles descend through various layers of the atmosphere, each characterized by individual turbulent properties, is not well understood. However, it is likely that the turbulent behavior of the atmosphere is a more important factor than gravitational settling in the descent of relatively small particles.

Rainfall hastens the descent of particles of all sizes, and also may cause the particles to penetrate the surface of the ground after they have settled. This penetration may be caused either by the simple transport of particles into the ground or by dissolving action, although the particles are only slightly soluble.

We have seen that the residual radioactivity in the cloud is the only characteristic of an atomic explosion which has an effect at any great distance from the site. Fall-out of particles carrying some of

[6] At any subsequent time, the remaining activity can be approximated by the relationship: activity$=A_1t^{-1.2}$, where $A_1$ is the activity at one unit of time ($t$) after detonation. Thus from a nominal weapon, the gamma activity of the fission products is estimated to be:

| *Time after detonation:* | *Fission product gamma activity in millions of curies* |
|---|---|
| 1 minute | 820,000 |
| 5 minutes | 120,000 |
| 1 hour | 6,000 |
| 1 day | 133 |
| 1 week | 13 |
| 1 month | 2.3 |
| 1 year | 0.11 |
| 10 years | 0.08 |
| 100 years | 0.006 |

[7] The micron, a unit of length, is equal to one-thousandth of 1 millimeter, or 0.000039 inch.



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this residual radioactivity, however, may occur in virtually any portion of the United States. The characteristics of fall-out, methods of measuring it, and its possible effects on human beings, animals, crops, and industry will be discussed in later sections of this report. However, an understanding of some basic facts concerning radiation is necessary before these questions can be evaluated.

*What Is Radiation?*

Light, heat, and radio waves are familiar kinds of radiation. Although nuclear radiations are less familiar to most people, all of us are subjected to them constantly without our being aware of them. They are invisible and undetectable by the unaided senses. However, their effects can be measured, just as a thermometer measures the effects of heat, and various instruments have been developed for this purpose.

Nuclear radiations are of two general types: (a) bits of nuclear matter—neutrons and alpha and beta particles; and (b) electromagnetic waves of the same general type as light, heat, and radio waves, but of very short wave length—the gamma rays.[8] (X-rays are similar to gamma rays, but they come from the outer parts of atoms, not the nuclei.)

Although man always has lived in a sea of nuclear radiation, he knew nothing about it until less than 60 years ago. In 1896, a French scientist, Becquerel, discovered natural nuclear radiation when he noted that film placed near chunks of an ore of uranium showed darkening after development, although it had not been exposed to light. Radium, another naturally radioactive substance, was discovered by Pierre and Marie Curie in 1898.

In only a few years subsequent to Becquerel's discovery, scientists in many countries learned a great deal about nuclear radiation. They identified the positively charged alpha particles, the negatively charged beta particles, and the uncharged gamma rays, and they discovered that the ability of these kinds of radiation to penetrate matter varies greatly. They began to apply nuclear radiation to the diagnosis and treatment of disease.

Shortly after the turn of the century, another kind of nuclear radiation was discovered—the cosmic rays. These high-energy rays have their origin outside the earth's atmosphere, but their exact source still is unknown.

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[8] Neutrons are uncharged penetrating particles. Depending on their speed, they can penetrate up to several feet of tissue. Alpha particles are relatively large, positively charged nuclei of helium atoms. They are unable to pentrate the unbroken skin, but can cause damage if an alpha-emitting substance is deposited within the body. Beta particles are small, negatively charged particles. Those emitted by fisson products will penetrate a maximum of about a third of an inch of tissue. Gamma rays are uncharged electromagnetic waves which are highly penetrating.

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*Radiation Measurement*

In order to study nuclear radiation, scientists had to develop instruments capable of measuring the effects of radiation. Of course, units of measurement also had to be established.

Nuclear radiation can be measured because it causes ionization in substances through which it passes or in which it is absorbed. In other words, the radiation causes atoms and molecules, which carry no electrical charge in their normal state, to separate into charged parts, called ions. In large measure, it is through this process of ionization that nuclear radiation can cause damage to our bodies.

Special instruments, such as the geiger counter and the ionization chamber, amplify the very small electrical currents caused by ionization and indicate them upon a meter. Instruments used for the detection of radioactive fall-out are described in a later section of this report. The units for measuring the ionizing effect of radiation are the roentgen (r), named in honor of the discoverer of X-rays; the roentgen equivalent physical (rep); and the roentgen equivalent mammal (rem).[9] A milliroentgen is one-thousandth of 1 roentgen.

Another unit by which radioactivity is measured is the curie, named for the discoverers of radium.[10] The curie is a measure of the number of disintegrations occurring in the radioactive substance itself, rather than of the ionization it produces in other substances. It is not possible to translate curie units into roentgen, rep, or rem units unless the energy and nature of the particles emitted by the radioactive substance are known, as well as other factors such as its distance from the substance irradiated.

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[9] By definition a roentgen is the quantity of gamma or X-rays that will produce 2 billion ($2 \times 10^9$) ion pairs in a cubic centimeter of air under standard temperature and pressure; it will deliver 93 ergs of energy per gram of tissue. A rep is a quantity of any radiation that will deliver an equivalent amount of energy (93 ergs) to 1 gram of soft tissue. This amount of radiation energy will produce about 1.6 million million ion pairs in tissue. A rem is a measure of the damage caused in tissue by 1 rep of gamma or X-rays. One rep of another type of radiation, delivering an equivalent amount of energy, may create more rems of damage than would 1 rep of gamma or X-rays. Estimates of the comparative effects of different types of radiation are as follows:

| | |
|---|---|
| Gamma or X-rays | 1 r=1 rep=1 rem. |
| Beta particles | 1 rep=1 rem. |
| Protons, fast neutrons | 1 rep=10 rem. |
| Slow neutron | 1 rep=5 rem. |
| Alpha particles | 1 rep=20 rem. |

[10] Originally the curie was defined as the number of disintegrations occurring every second in 1 gram of radium. However, the accepted definition today is that a curie is that quantity of radioactive material in which 37 billion disintegrations per second occur. Thus, the curie, rather than some unit of mass, is used to define the quantity of radioactive material. Curies of different radioactive materials may vary greatly in weight. For instance a curie of radium weighs nearly 1 gram, a curie of uranium 238 weighs 2,900,000 grams, and a curie of iodine 131 weighs only 0.0000078 gram.

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*Background Radiation*

As scientists learned to detect and measure nuclear radiation, they learned that we constantly are being exposed to radiation from a variety of sources in the air, water and the earth. A number of radioactive substances occur naturally, and they are widely distributed in the earth's crust. It is estimated that a layer of soil 1 foot thick and 1 square mile in area will contain, on the average, more than 1 gram of radium, 3 tons of uranium, and 6 tons of thorium. In addition, cosmic rays constantly bombard the earth. Cosmic rays and the nuclear radiation from uranium, thorium, radium and other radioactive materials in the earth's crust and in the air constitute what is called background radiation.

Background radiation varies in intensity depending upon time of day, altitude, the geology of the area, and, to a minor extent, latitude. For example, at sea level in the northeastern part of the United States, about 6.5 cosmic-ray particles per minute cross a horizontal surface 1 square inch in area. At 15,000 feet above sea level, about five times that number will be observed, and at 55,000 feet elevation the rate is about 75 times that at sea level.

Rainfall also may increase background radiation. The exact mechanism causing this increase is unknown, but it is believed that either the falling rain droplets absorb the minute radioactive particles naturally occuring in the air, or the downward air flow accompanying the rainfall blows these particles toward the earth's surface. Background radiation may increase as much as tenfold as a result of rain or snow.

Alpha, beta, gamma and cosmic radiations are included in "background," but because of the penetrating properties of the latter two, they are the principal components to be considered.

Human beings receive between 80 and 800 milliroentgens (0.08 to 0.8 r) per year from natural background sources.

*Radioactivity in Plant and Animal Tissue*

Since radioactive materials are widely distributed in the earth, air and water, it is not surprising that they occur naturally in the tissues of human beings, animals and plants. Radioactive isotopes[11] of such essential elements as carbon and potassium are incorporated into body tissue along with the more common stable forms. Water from many natural sources contains traces of radium, which accumulates in the

[11] Isotopes are forms of an element having the same atomic number but different atomic weight. Isotopes may be radioactive or stable. Radioactive isotopes often are called radioisotopes.

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skeleton once it is taken into the body. The radioactivity normally present in tissue is minute and not harmful to health, but it may be measured in the laboratory.

*Radiation from Other Sources*

Since the discovery of X-rays and radium, the penetrating power of radiation has been used increasingly in medicine and in industry. Many thousands of persons have been exposed to X-rays as an aid in the diagnosis of diseases such as tuberculosis, to determine the extent of body injuries, such as broken bones, or to locate foreign objects within the body.

The amount of radiation to which the patient is exposed is many thousands of times the level of background radiation, but generally is well below the level considered harmful. These exposures are usually to one part of the body, rather than to the whole body. Much larger exposures can safely be given to body parts than can be given to the whole body. Typical exposures during X-ray examinations are:

| | |
|---|---|
| Routine chest X-ray | 0.05 to 0.3 r. |
| Routine gastro-intestinal X-ray | 1.0 r per exposure. |
| X-ray of extremities | 0.25 to 1.0 r. |
| Fluoroscopic examination | 10 to 20 r per minute. |

As we have seen, normal background radiation ranges from 0.08 to 0.8 r per year.

X-rays, radium, and radioisotopes produced in nuclear reactors also are used in the treatment of certain kinds of skin diseases, tumors, cancer and allied diseases. In these instances, the ionizing effect of radiation is used to destroy diseased tissues. The exposures normally are much greater than are used for diagnostic purposes. A small skin cancer may be exposed to 4,000 r of X-rays of relatively low energy with little effect on the patient except for damage to the cancer cells and some scarring of adjacent tissue. A single exposure of only one-tenth that amount of penetrating X-rays, given simultaneously to all parts of the body, would be likely to result in death to one-half the persons so exposed.

Industrial uses of radiation are varied, ranging from inspection of castings through the use of high-voltage X-rays to the use of radium-containing paint on watches and instrument dials. The radium dial on a good wrist watch contains about one-millionth of a gram of radium. This produces considerable beta radiation at the outer surface of the watch crystal. Through the back of the instrument, however, there will be only gamma radiation, amounting to

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about 1 milliroentgen per hour to the wrist. Instrument dials in aircraft also are frequently marked with radium-containing paint. At the face of these instruments, levels of from 5 to 10 milliroentgens per hour sometimes occur, and in some aircraft the pilot is exposed to about 1 milliroentgen per hour.

*Radiation from Nuclear Weapons Tests*

Radioactive fall-out may cause a detectable increase in background radiation. Fall-out can have a damaging effect on certain materials which are especially sensitive to radiation, such as are used in the manufacture of photographic supplies or radiation detection instruments. Fall-out also may affect measurements of radiation in exploration for uranium ores or in scientific research involving low levels of radioactivity.

One of the principal purposes of the fall-out monitoring system maintained across the country during test periods is to keep sensitive industries and laboratories informed of fall-out levels. With adequate warning, they may be able to take precautions to prevent fall-out from interfering with their operations.

## Pre-test Precautions

The decision to detonate a nuclear device at the Nevada Proving Ground sets into motion a series of activities designed to assure the safety of persons on the site and throughout the Nation. The most important of these is the forecasting of weather conditions at the scheduled time of the detonation. If weather forecasts are unfavorable, the test is postponed.

Pre-test warnings are issued to nearby communities and to individuals who may be in the vicinity of the site. The Civil Aeronautics Authority is notified so that air lines and private pilots may be warned away from the projected path of the radioactive cloud. These precautions are described in further detail below.

### Weather Determination

It has been noted that weather conditions affect the direction and intensity of blast waves. Weather also is the major factor affecting the direction and intensity of fall-out. Such conditions as precipitation, cloud cover, temperature, temperature inversions and wind directions and velocities must be taken into consideration before a test is held.

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Accuracy in forecasting the direction and velocity of wind is particularly difficult at ground surface in the mountain-surrounded valley where the detonations occur, since winds may circle the compass in a few moments. Following one detonation last spring, the radioactive cloud column was sheared by wind into three clouds—one low-level, one medium-level, and one high-level—each of which moved away from the proving ground in a different direction. The pre-detonation forecast had predicted this, and had anticipated that precipitation would occur downwind in one direction.

The usual weather report contains only a fraction of the data necessary to make such predictions. In order to obtain more comprehensive data, the United States Air Force Air Weather Service has established a permanent weather unit at the proving ground. This unit receives full reports on hemispheric and localized weather conditions from the hundreds of stations of the Air Weather Service and the United States Weather Bureau. Additional information on weather in the site area is provided by a network of stations ringing the test site.

### *Pre-Detonation Forecasts*

Forecasts for the test hour and date are made 72 hours in advance of the scheduled time. If the outlook 24 hours in advance remains favorable, the operational sequence is begun. On the evening before a test, all factors pertaining to the operation and to public safety are reviewed and evaluated by the test manager, the test director and their scientific advisors, including an advisory panel consisting of experts in the fields of biology and medicine, public health, meteorology, and blast. At this meeting, detailed consideration is given to factors affecting radioactive fall-out. These include the following:

(a) The type of detonation. A high air burst, for example, probably would not result in significant amounts of fall-out.

(b) The probable maximum height of the cloud, and wind speed and velocity at that altitude. If the cloud moves slowly, its radioactivity will have diminished greatly before it reaches any populated areas. On the other hand, fast winds tend to spread the cloud and disperse the radioactivity through the atmosphere more quickly.

(c) The possibility of downwind rain or snow. If there is a probability of precipitation anywhere downwind toward communities within 200 miles of the site, the detonation probably would be postponed.

(d) The pattern and nature of fall-out within a 200-mile radius. If there is any likelihood of unusually heavy fall-out on a nearby community, the test would be postponed.

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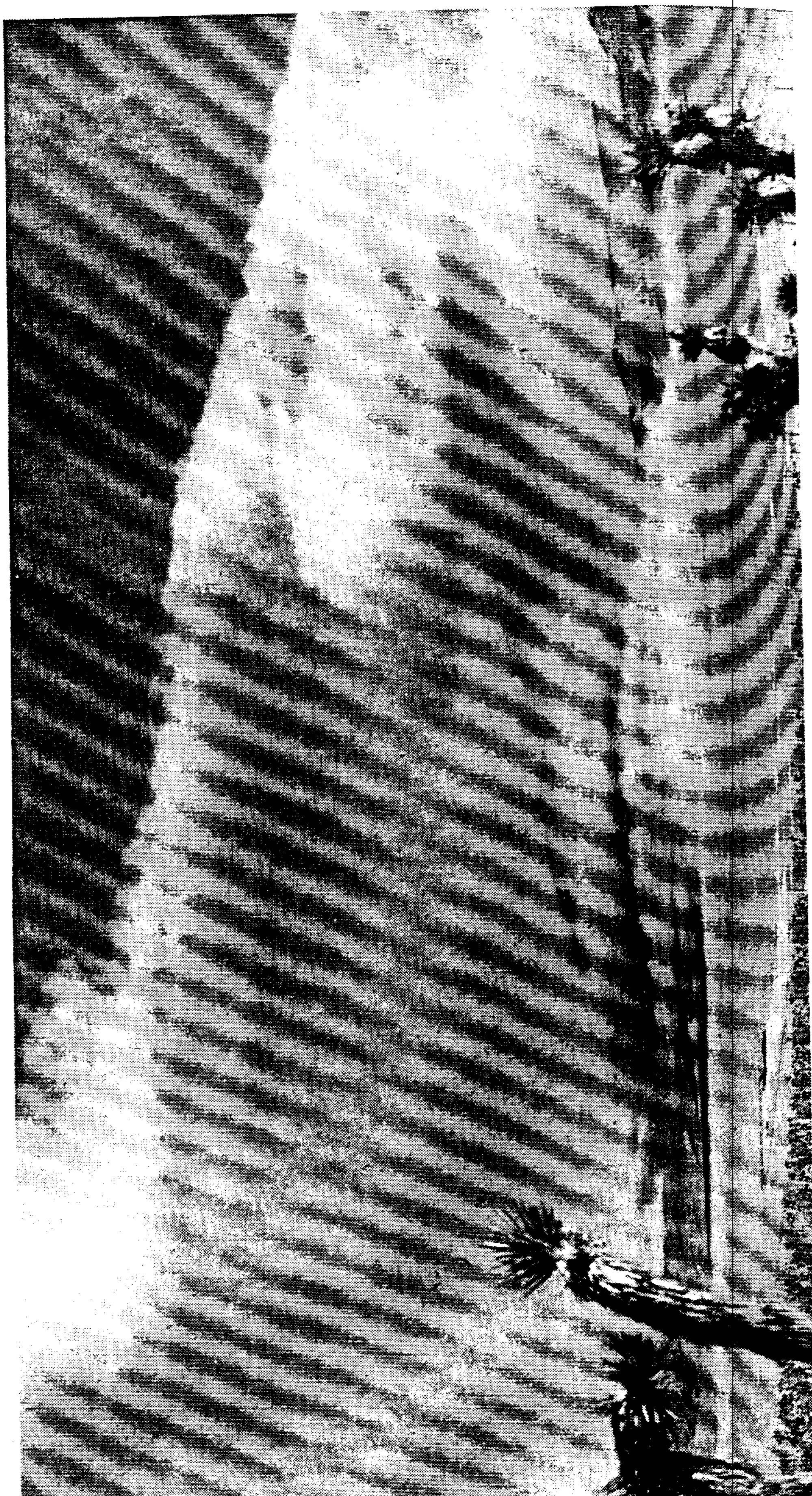

The shearing effect of wind is illustrated by the above photograph, which shows the low-level dust cloud following a *test detonation* as it is spread in several directions by wind at different altitudes.

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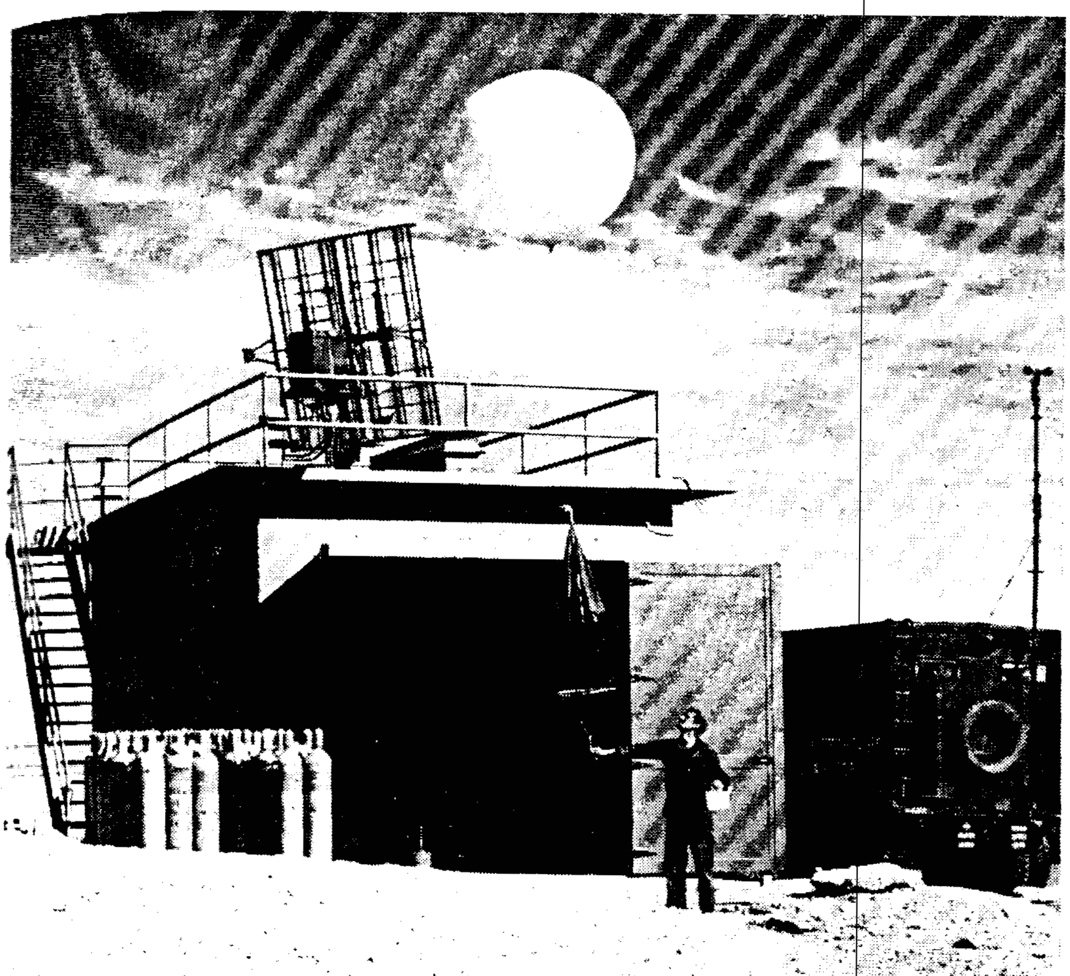
(e) The commercial air line flight areas which may be affected.
(f) The placing of monitoring equipment and of monitoring and warning personnel along the projected path of the fall-out.

These and other factors must be considered both from the standpoint of public safety and that of conducting a successful test operation. If conditions are favorable, the order to proceed with the test is issued. Adverse developments, however, can cause a postponement at any time up until 10 minutes before the detonation. Evaluation meetings may be held at various hours through the day or night if there is any uncertainty regarding weather forecasts.

## Pre-Test Warnings

Various pre-test warnings are issued. Advance notice of each test series is made, and before each detonation it is announced that a test



**The United States Air Force weather station shown above is located near the Control Point at the Nevada Proving Ground. During continental tests, weather personnel send many helium-filled Raob (radar-observer) balloons to the upper atmosphere to check on temperatures, dew points, humidity and wind velocities. The radar tracking instrument, located on top of the test weather station, charts wind velocities and directions to determine cloud paths after detonations.**

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is expected to occur within a stated period of time. Helicopter and ground patrols and posted notices are used to warn desert migrants and hunters to avoid the proving ground region. Officials of communities around the proving ground and cattlemen using adjoining ranges are notified a few hours before a test. Other notifications are issued following the detonation. News media are advised of the height of the cloud and its general speed and direction. Health officers of Nevada and of adjacent states in the path of the cloud are advised by telephone so that they will be prepared to report and to interpret fall-out levels in their localities. In some instances, Civil Defense organizations have been notified so that their monitoring personnel might gain field experience.

Care is taken to prevent airplanes from flying into the radioactive air mass. Before each shot, a general broadcast is made through Civil Aeronautics Authority facilities, warning anyone who plans to fly anywhere within a specified circle within specified hours to request a safe routing from the CAA. The specified area is called the warning circle. The CAA is advised of a zone within the warning circle which will be closed to air traffic. A typical air space closure is shown on page 101.

## The Radiation Monitoring System

Fall-out radioactivity following test detonations is recorded by a monitoring system which extends across the Nation. Its principal purpose is that of protecting test personnel and the public by determining the radioactivity deposited in various localities by fall-out. The monitoring system also provides information regarding the relation of fall-out to weather conditions, the type of burst, and properties of the radioactive cloud. In addition, the collected data are used for the guidance of industries which are sensitive to minute increases above normal background radiation. Monitoring also provides meteorologists with a new method of studying the movement of large masses of air at varying altitudes.

The Radiological Safety Group of the test organization monitors fall-out within a 200-mile radius of the test site. The Armed Forces operate additional monitoring teams when military personnel participate as fox-hole observers or in tactical exercises. Military units man helicopters and other aircraft used for sampling and tracking the radioactive cloud over the site and out to a distance of 600 miles.

On the ground, the responsibility for monitoring fall-out outside the 200-mile zone rests with the National Monitoring System, operated by the New York operations office of the Atomic Energy Com-

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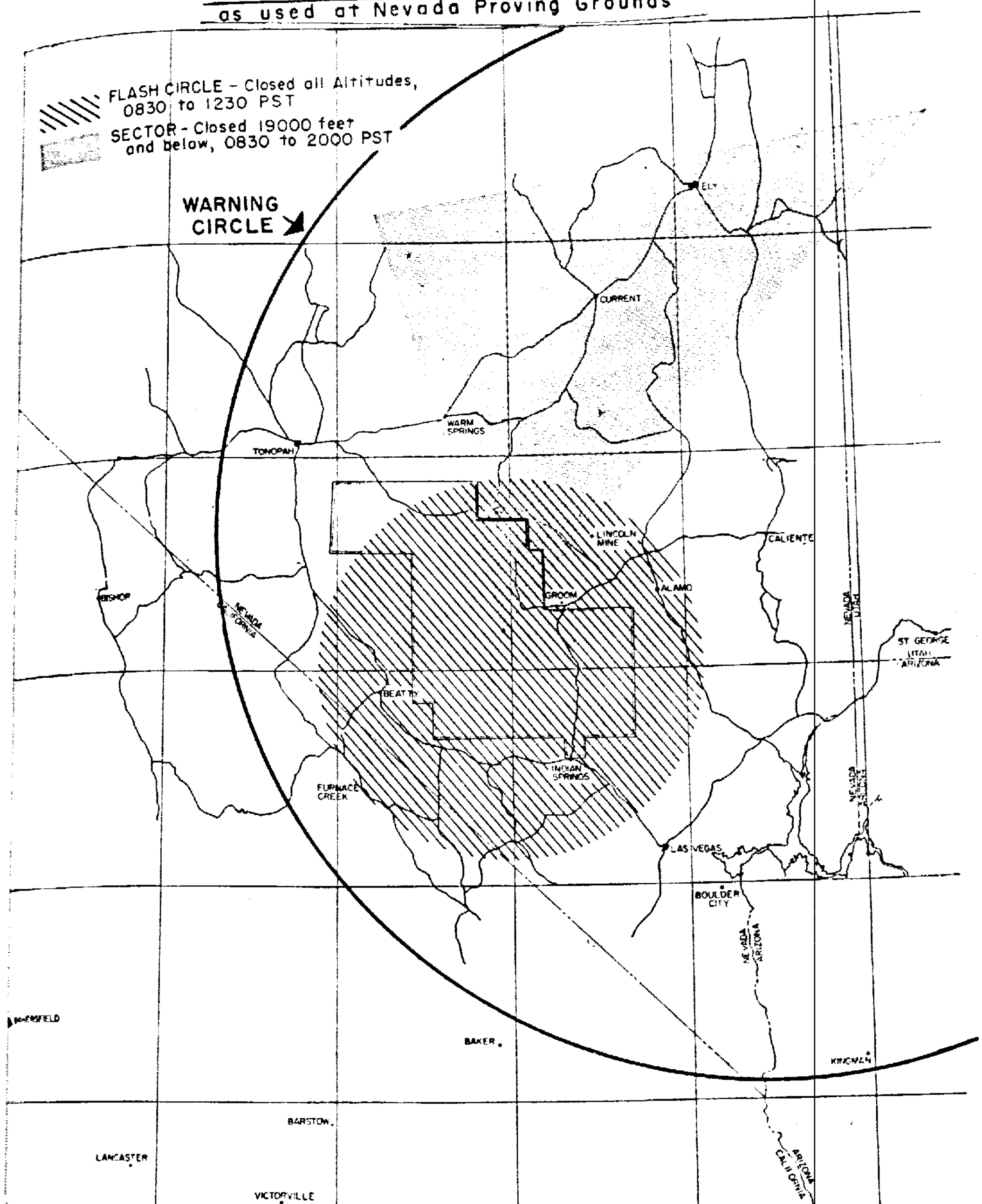
TYPICAL CAA AIR SPACE CLOSURE
as used at Nevada Proving Grounds




mission. This system includes two types of monitoring operations. Two-man mobile monitoring teams operate at varying locations within the 200–500-mile zone, and a total of 121 fixed monitoring stations, located at United States Weather Bureau Stations, monitor at various locations across the Nation.

## Instruments Used in Monitoring

Various instruments are used by monitors to take samples of radioactive dust and to measure its activity. Airborne dust is collected

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on filters through which air is drawn as it is through a household vacuum cleaner. Settled dust is collected on flat trays covered with gummed paper. Special instruments may be used to sort out the particles in relation to their weight, permitting a determination of the particle size distribution.

The distribution of particle sizes in fall-out on a locality may affect the relationship between radioactivity in the air and in settled dust. Large particles fall relatively rapidly, and very small particles tend to remain suspended in air. Therefore, measurement of both air-borne and settled radioactivity is useful in determining fall-out in an area.

Different types of instruments may be used to measure the activity of dust samples or the general level of external radiation in a locality. Ionization chamber types of instruments collect the very small electrical currents caused by the ionizing action of radiation and amplify them so that they may be read on a microampere meter. A geiger counter is a special type of ionization chamber, which counts individual particles or gamma rays.

### *Interpreting Instrument Readings*

Care must be exercised to interpret the instrument readings correctly. In using a geiger counter, which is sensitive to both gamma and beta radiation, both a gamma-beta reading and a gamma-only reading should be taken to determine the relation of the beta activity to the total radiation level. (Since the beta particles are relatively nonpenetrating, they may be shielded out when a gamma-only reading is taken.)

Beta particles are of little importance in determining exposure from external radiation because of their limited ability to penetrate tissue. Since the beta radiation level as measured by monitoring instruments may be several times greater than the gamma level, failure to discriminate between the two can result in a reading which appears alarmingly high to an untrained observer. A similar result may be obtained from reading only the "hottest" spots in an area. For example, fall-out from a large area may be collected in a puddle of water, which will show a much higher radiation level than the surrounding terrain.

In interpreting the effects of fall-out radiation, it also must be remembered that the radioactivity decays rapidly. A reading taken immediately after the fall-out must be interpreted properly to determine total exposure for the following week or month. To take an accurate reading, the normal background for the locality should be

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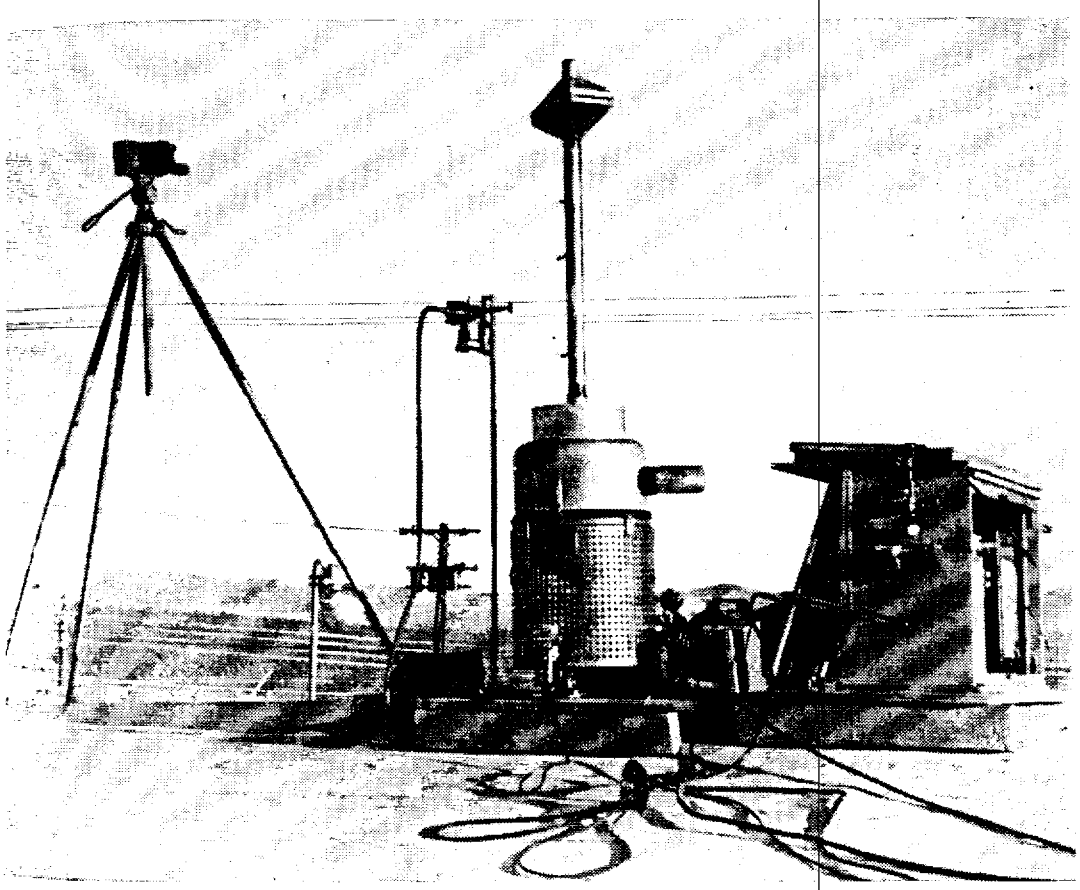
known, and the instrument should be checked against a standard radiation source to determine its accuracy.

## Monitoring Within the 200-Mile Zone

During the spring 1952 test series, the radiological safety group of the test organization consisted of 180 persons drawn from the staff of the Commission, its contractors, the United States Public Health Service, and the Armed Forces, including an Army Chemical Corps Company. The work of this group after a typical test is as follows:

As soon after detonation as visibility permits, a radiological survey is made from two helicopters or L–20 type aircraft. At approximately the same time, ground survey teams move toward the target area in jeeps. They monitor radiation intensities, establish safe operating procedures, and insure that test personnel are not overexposed to radiation. Their findings are used by military commanders to determine when military groups may move forward for tactical exercises.



One of the air-sampling stations established at 15 inhabited locations within the 200-mile zone during test operations at the Nevada Proving Ground.

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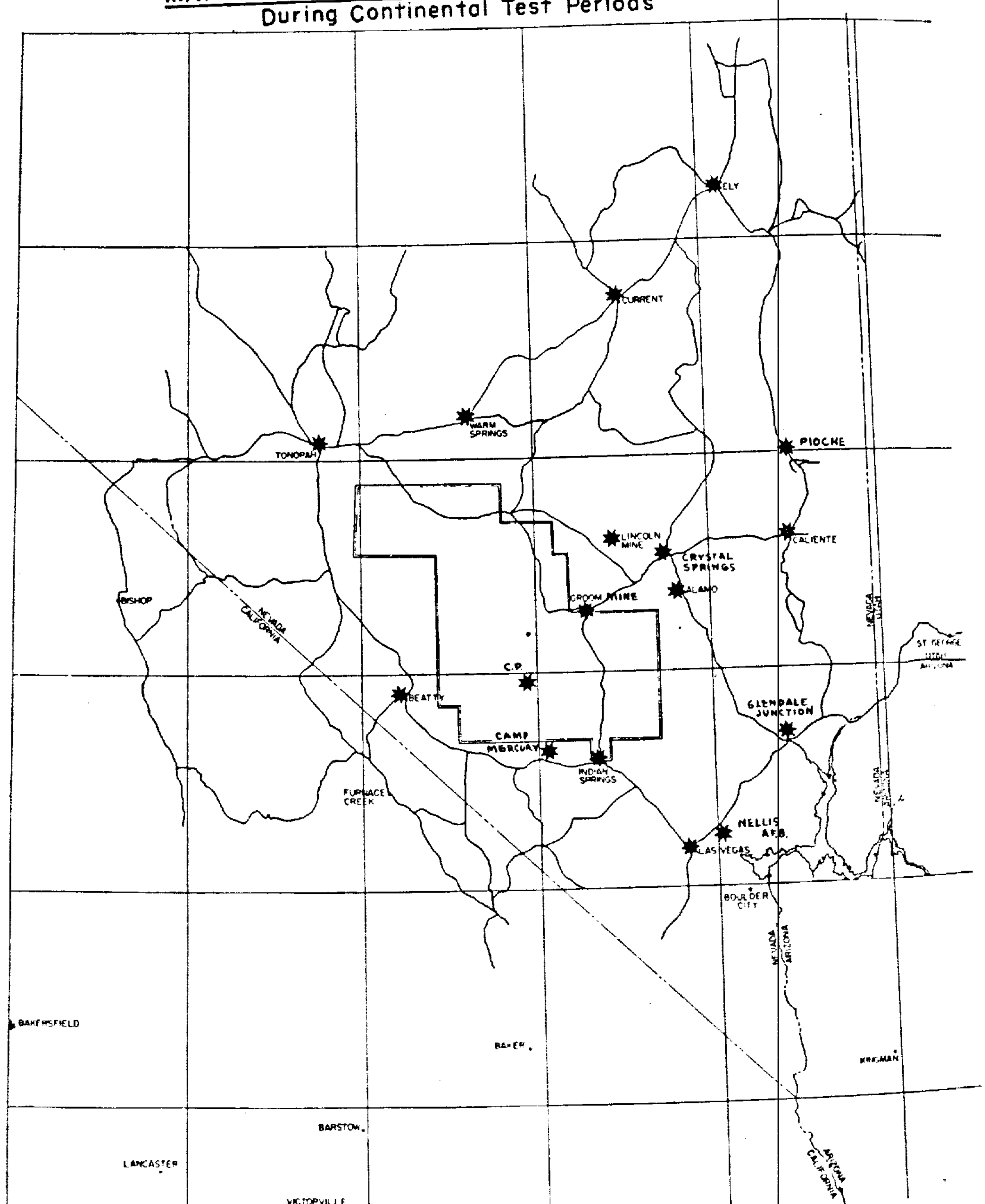
Other members of the group monitor the area up to 200 miles from the site, using aircraft and motor vehicles. They are in radio communication with the proving grounds control point. Fixed air sampling stations are established at approximately 15 inhabited locations, as shown on the map below, and other sampling is performed in areas immediately adjoining the site through collection of dust particles.

Cloud-tracking aircraft teams follow the radioactive air mass for approximately 600 miles in order to determine its path. This determination facilitates ground measurements and provides data for controlling air lanes.

The off-site monitoring teams are prepared to advise the residents of communities near the site if any precautionary measures should be

MAP OF ROUTINE AIR SAMPLING STATIONS
During Continental Test Periods



taken as a result of fall-out. The most important of these, which would reduce radiation exposure appreciably, would be to have the residents remain inside their homes or business places for a few hours. If radiation approached a level which might be hazardous, the monitoring teams would advise authorities in the community and would assist in evacuation of residents. Such measures never have had to be taken. Prior to one test in the spring 1952 series, 11 persons living at the Groom mine, 20 miles from the firing area, were asked in advance to leave. They spent one night away from the mine and returned shortly after the detonation.

### Mobile Monitoring in the 200–500-Mile Zone

Mobile teams of the National Monitoring System operate within the 200–500-mile zone. During the spring 1952 test series, the constitution of the mobile monitoring force was typical. It included 2 AEC specialists, who directed operations, 16 enlisted men of the Army Chemical Corps under command of a Chemical Corps officer, and 2 Air Force C–47 aircraft and crews. The permanent field headquarters of the mobile force was Hill Air Force Base at Ogden, Utah, but the field headquarters was shifted to Air Force bases at Albuquerque, N. Mex., for one test and to Sacramento, Calif., for another in order to be nearer the projected path of the cloud.

When the weather forecasts are made before a test, the field headquarters issues instructions for deployment of the two-man mobile teams. They are flown to their assigned locations, and on arrival establish communication with the field headquarters by phone or CAA Airways Communication System. Then they set up their monitoring equipment and begin to take measurements, with the objective of establishing the level of background radiation before the cloud arrives.

Each team takes samples of settled and of airborne dust. Special samplers separate the airborne dust according to its particle size. In addition, the general radiation level at each locality and the radiation level of certain of the dust samples are measured periodically with three different types of portable survey instruments, one of which differentiates between the beta and gamma components.

Sampling continues for 36 hours after the shot or until any rise in the radiation level has dropped to approximately the background level. The teams record weather as well as radiation data during the sampling period.

Instrument readings are transmitted periodically to the field headquarters, from which they are relayed to the test organization. Filter paper and gummed paper samples are sent to the New York operations office for counting.

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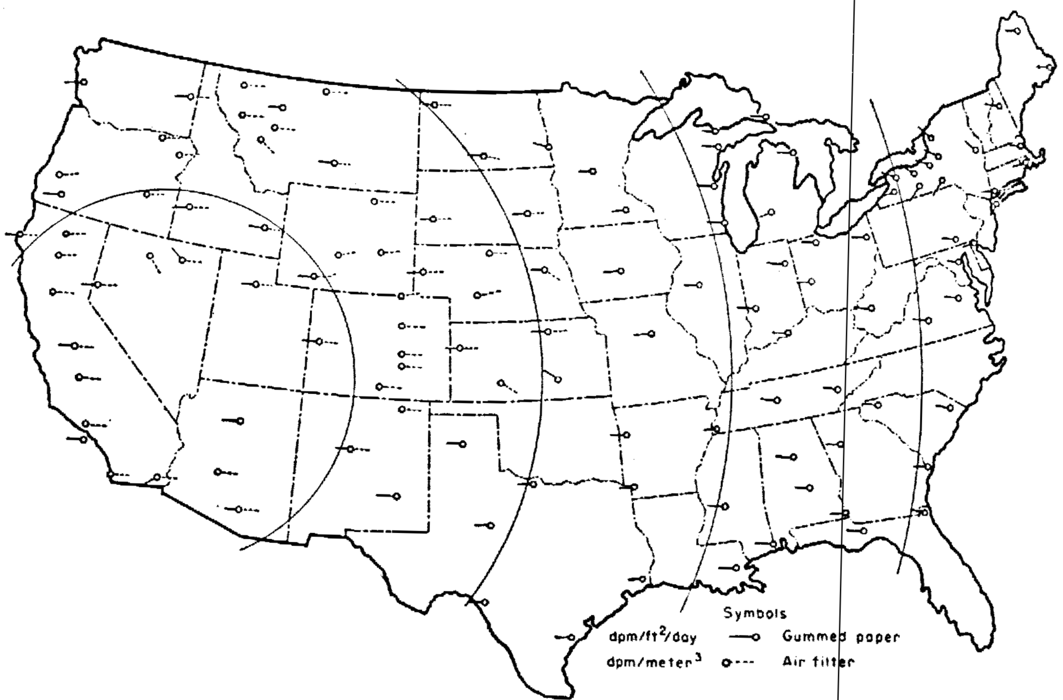
## Fixed Monitoring Stations

The fixed monitoring system which covers the entire United States 200 miles from the test site to each coast, operates continuously during the test periods. Fixed monitoring stations make no on-the-spot measurements; all samples are sent to New York for counting.

Two methods of sampling are used. Each of the 121 United States Weather Bureau stations in the fixed monitoring network collects gummed paper samples of settled dust daily. About one-half the stations also collect high-volume filter paper samples of airborne dust, using the same kind of sampling equipment as the mobile teams. Each station records the weather observed during the sampling period and transmits this information with the samples daily to New York.




**Locations of the 121 fixed monitoring stations are shown on the above map. The symbols indicate whether the stations use air filters, gummed paper or both to collect fall-out samples. The arcs are 500 miles apart.**

## Counting of Samples

When the samples are received in New York, the weather information is recorded on a special punch card, and a number given to the sample. The sample is dry ashed in an electric furnace, and the ash is placed in a plastic planchet marked with the sample number.

These planchets are sealed between two vinyl plastic tapes and assembled into rolls of 100 samples each. The rolls are then placed on especially designed automatic beta counting instruments, and the activity of each sample is counted for 20 minutes or 640 counts, which-

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ever comes first. The sample number and count are printed automatically on a paper strip, and the count later is transferred to the original punch card for centralization of data and ease of study.

On the basis of the previously determined rate for fission product decay, activities measured at the time of counting are extrapolated to the midpoint of the sampling day and marked on the punch card as "disintegrations per minute per square foot per 24 hours" (d/min/ft$^2$ 24 hr) in the case of gummed paper samples, or as "disintegrations per minute per cubic meter of air" (d/min/m$^3$) in the case of filtered air samples.

## Cooperation With Other Groups

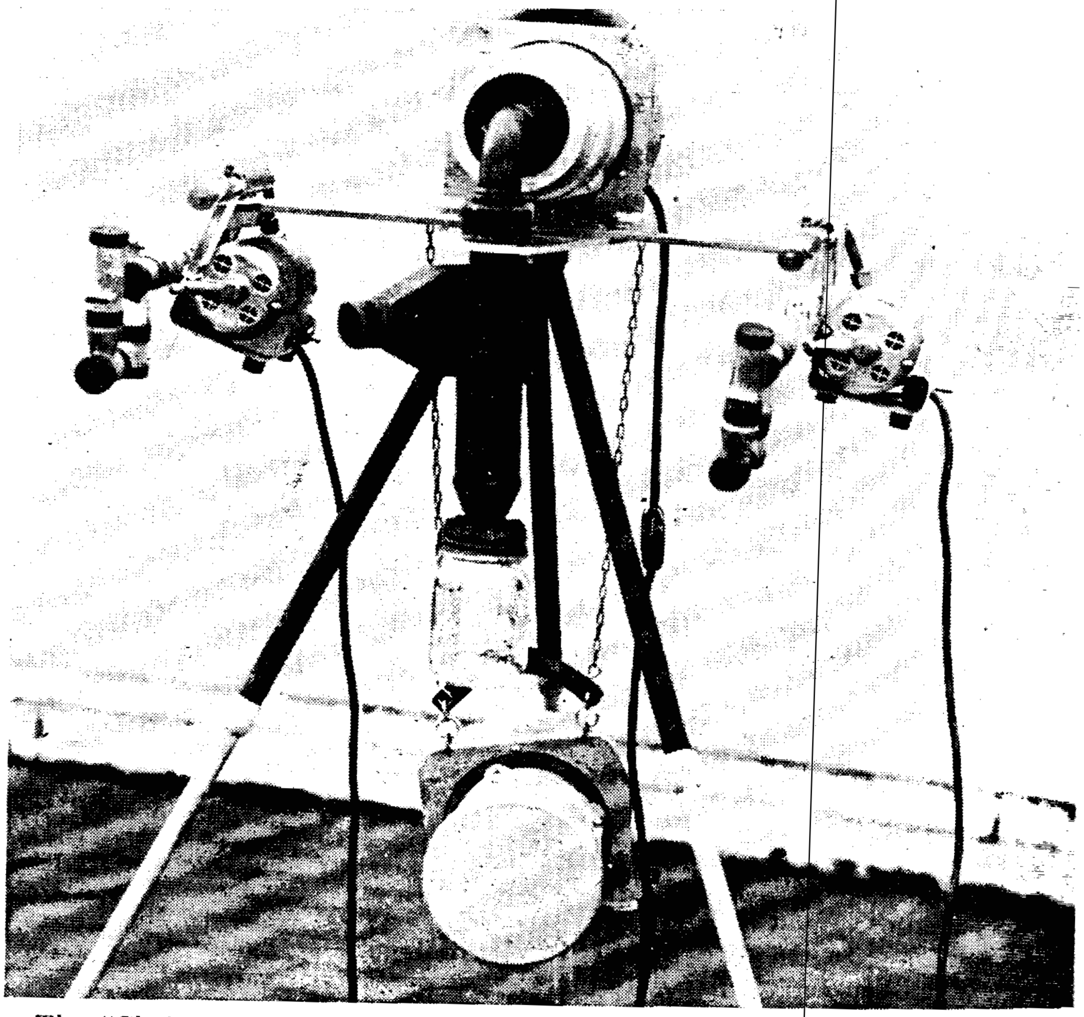
In carrying out the National Monitoring System, the AEC has received cooperation and assistance from many agencies of Federal and State Government from industrial associations, and from private institutions and citizens. The collection of samples at the 121 fixed stations is done by personnel of the United States Weather Bureau. Weather Bureau scientists are active in interpreting the fall-out data in an attempt to correlate it with weather phenomena. The United States Chemical Corps has provided personnel for the mobile monitoring teams, and the United States Air Force supplies air transportation for the teams.

State and Federal public health departments have assisted the National Monitoring System in the collection of samples on occasion, and have interpreted data in response to inquiries for the press and public, as have universities and private laboratories.

Close liaison has been maintained with the National Association of Photographic Manufacturers to assure that that industry is informed of test programs. This procedure has assisted the photographic industry in planning and monitoring operations involving radiosensitive products. Similarly, laboratories and other industries that may be inconvenienced by slight increases in background radiation have been kept informed of the levels found, and have been given as much prior notice of test programs as national security would allow.

# *The National Monitoring System*

The following photographs illustrate the methods used by the National Monitoring System to measure radioactivity deposited across the Nation by fall-out. The pictures show how samples of settled dust are collected on gummed paper, and how vacuum devices are used to collect samples of air-borne dust on filter paper. Also illustrated are the steps taken to measure and record the radioactivity of each sample.



The "Christmas Tree" is used by the mobile teams to sample dust which is suspended in the air. Samples are taken for periods of 20 minutes to 2 hours during the 48 hours after a test. At either end of the crossbar is a low volume particle size sampler through which air is pulled at the rate of one-half a cubic foot per minute. As they are drawn through the sampler the dust particles are separated according to size and collected in different bottles. At top and center are high-volume samplers which draw a cubic meter of air per minute and sample the total concentration of dust.

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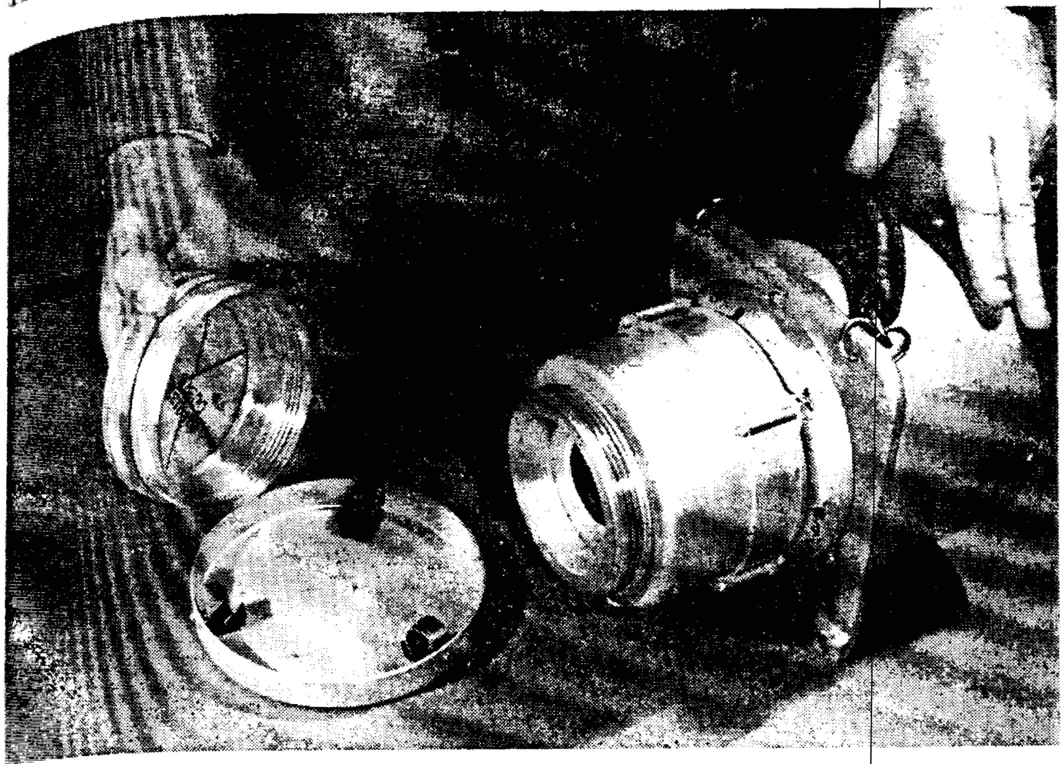
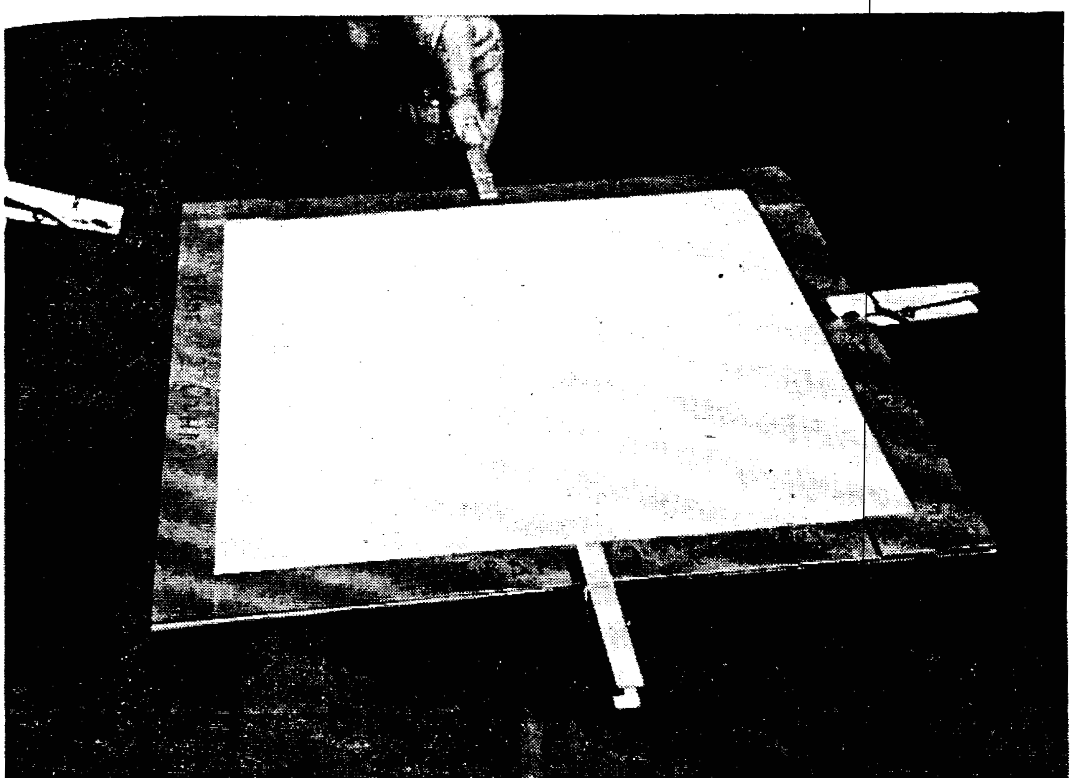
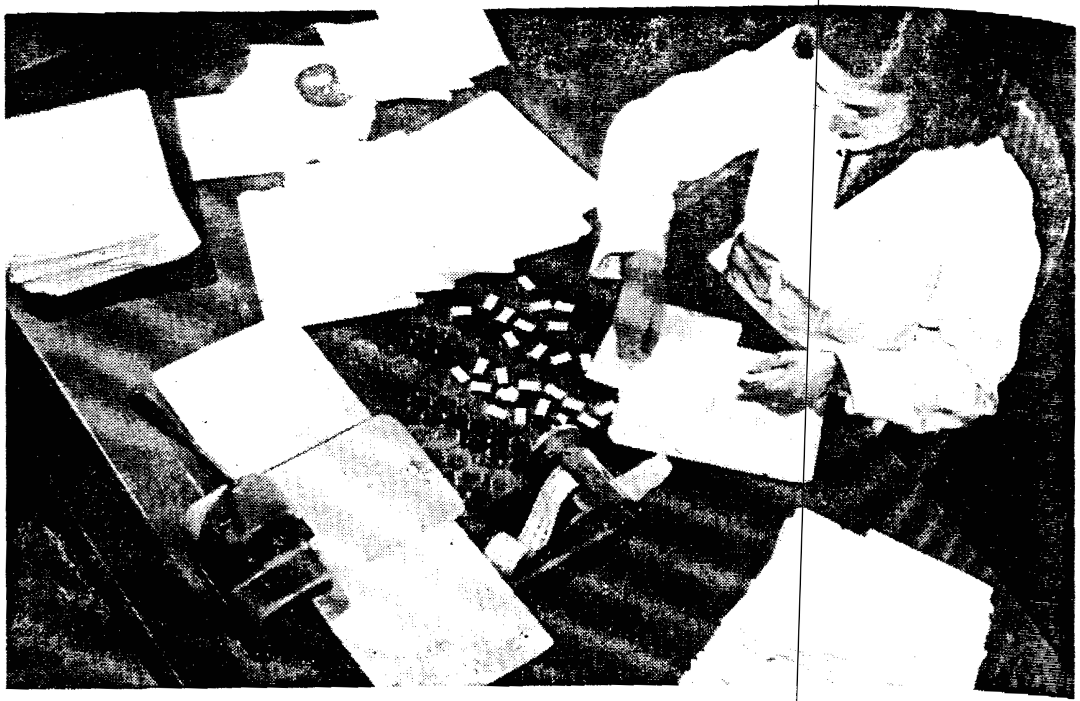


A suction device called an air sampler, through which an air flow of 40 cubic feet a minute is maintained, is used at some of the fixed monitoring stations. The filter paper and wire retainer at left are fastened on the front of the sampler and are protected by a metal cap (center). The air is drawn in around the edges of the cap and the suspended particles are deposited on the filter paper.



Dust is collected on a 1-foot square sheet of gummed paper placed on a 3-foot high stand in one of the two sampling methods used at fixed monitoring stations. The sheets are changed every 24 hours.



Duplicates of an identifying number are placed on the sample when it is received from the field, on the planchet in which it will be measured and on the data card where the measurement will ultimately be recorded.

The technician at left folds samples and places them in crucibles for ashing in the furnace. At right, a technician grinds the ashes and places them in the numbered planchets for measuring.

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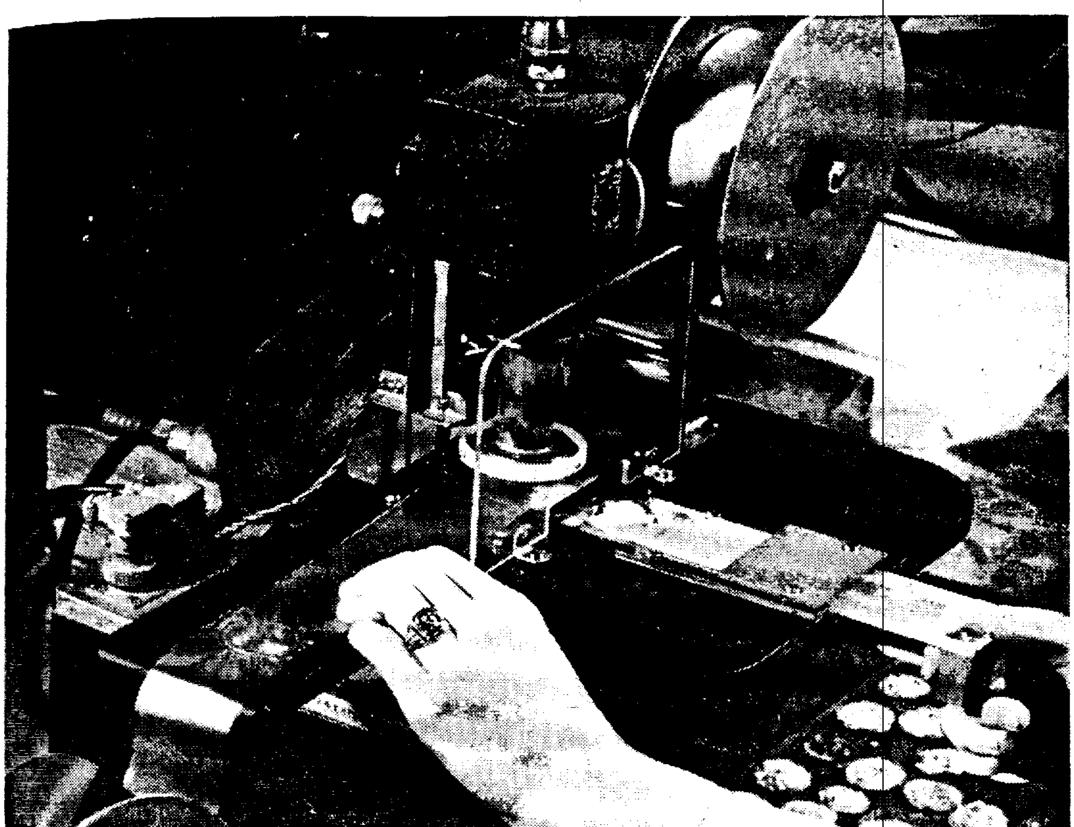
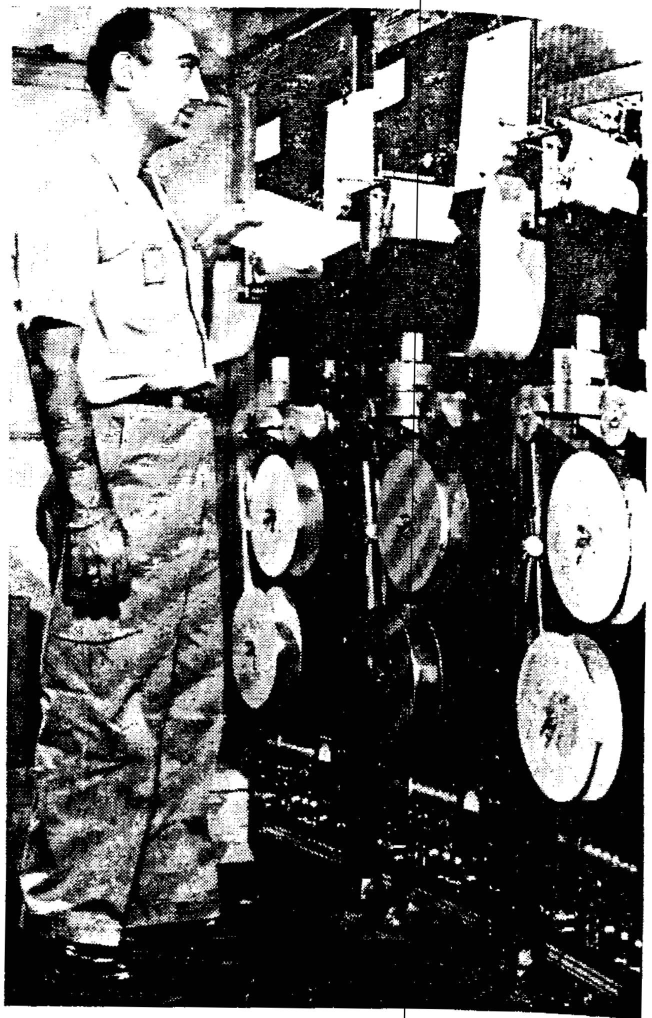
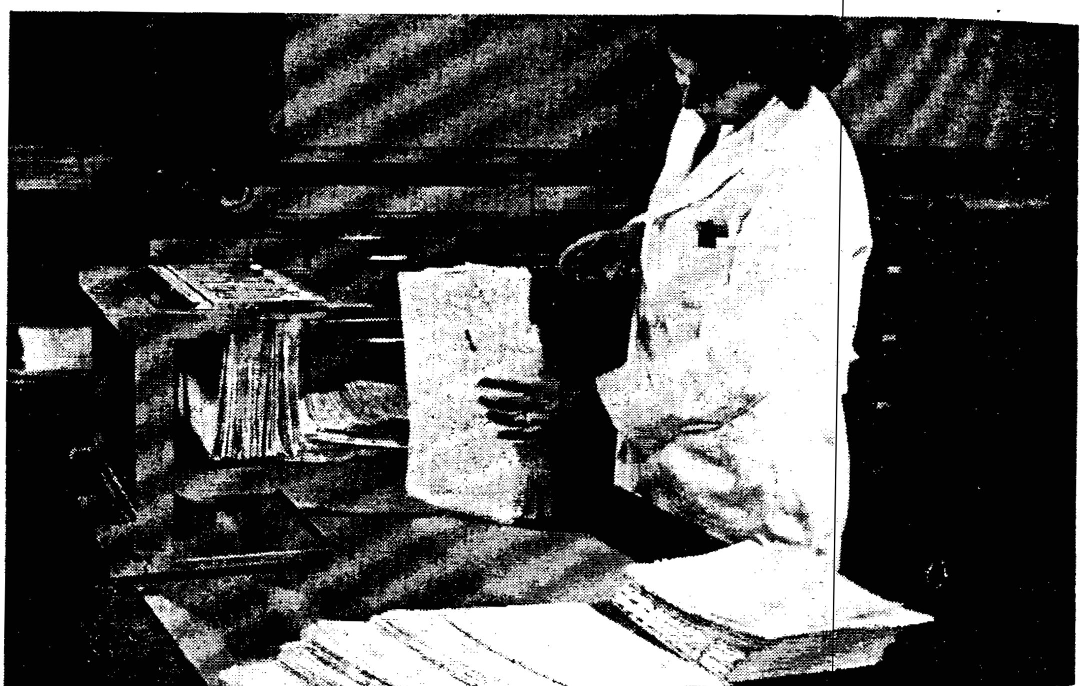
The crucibles containing the folded samples are placed in an oxygen-fed furnace for ashing.



The numbered planchets are sealed between two rolls of polyvinyl tape at 8-inch intervals.

Rolls of 100 samples each are loaded on an automatic counting apparatus. Each sample is counted for 20 minutes or 640 counts, whichever comes first. The sample's position on the tape, the count and the counting time are stamped out on the paper roll by the printing recorder. The equipment used in the processing of samples makes possible the counting of 400 to 600 samples per day.





Data from the counting room are transferred to the data cards. Various methods for punching and sorting the cards make the development of specific subject data possible.

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# Fall-Out and Public Health

The body may safely receive a small dose of radiation because the effects are repaired virtually as rapidly as they are produced. A large number of small doses may be given over a period of time, as the body is able to repair itself between doses. Over a period of many years, a human being may safely receive a total amount of radiation which would cause a fatal illness if administered to his whole body within a period of a few minutes.

The body's ability to repair radiation damage has been taken into account in the establishment of maximum permissible radiation doses by two scientific bodies—the National Committee on Radiation Protection and the International Commission on Radiological Protection. The maximum permissible levels recommended by these groups include safety factors; that is, they are considerably lower than the radiation level which causes any observable bodily change.

In the following section, radiation exposures resulting from fall-out will be evaluated in the light of the maximum permissible doses for both external and internal radiation. It will be seen that of all the tens of thousands of measurements taken, none has shown a dangerous concentration of radioactive materials outside the proving ground.

## Maximum Permissible Levels for External Radiation

Roentgenologists have been exposing themselves to X-rays for the past half-century, not always realizing their danger. Through long study of the effects of such exposures, it has been determined that a dose of 0.3 roentgen per week may be delivered to the whole body for an indefinite period without hazard.

The maximum permissible weekly rate of exposure is designed to assure safety for persons regularly exposed to penetrating radiation over periods of many years. It does not mean that 0.3 roentgen is the largest exposure which may be incurred in 1 week without hazard. The lowest dose which will produce detectable effects on the blood when given in a few minutes or hours is about 25 roentgens. But even this dose, so far as is known, will not cause any damage which the body cannot repair. An individual could not safely receive such a dose daily, and probably not even monthly, but occasional exposures well above 0.3 roentgen will have no detectable bodily effect.

An ad hoc committee composed of authorities in the fields of medicine and roentgenology has given careful study to the exposures which may be safely received by the public as a result of nuclear test detonations. This committee advised the United States Atomic Energy

Commission that a total dose of 3 roentgens in any period of 10 weeks would not exceed safe levels. The dose of 3 roentgens may be received as a result of a single exposure or a number of successive, smaller exposures, but the total exposure during the 10 weeks should not exceed 3 roentgens.

## External Radiation from Fall-Out

None of the measurements of fall-out radioactivity outside the Nevada Proving Ground has exceeded the recommended maximum of 3 roentgens per 10 weeks. Nearly all the measurements have been far below this level.

The highest radiation level detected anywhere outside the proving grounds was at one of the two mines located nearby. Here, measurements showed a radiation level which would deliver an estimated dose of 1.75 roentgens during the first 10 weeks following fall-out and 2.25 roentgens during a lifetime. This level, the highest recorded as a result of any series of tests, is well within the limits recommended for public safety during nuclear tests.

Monitoring teams were stationed at both mines during the tests because of their proximity to the test site. As has been noted previously, persons living at one of the mines were asked to leave prior to one test, but returned the next day.

The highest gamma radiation levels recorded in cities and towns in the 200–500-mile zone were between 1 and 2 milliroentgens per hour. These levels rapidly decreased because of the radioactive decay of the fall-out material. Calculations show that if an individual remained over the material for an entire lifetime, he would receive a total dose of about 50 milliroentgens—one-sixth of the maximum permissible dose for 1 week.

Measurements in towns within the 200-mile zone, with one exception, showed only slightly higher values. The lifetime dose in this one community would be approximately 0.5 roentgens.

Although some radioactivity from fall-out has been detected at all of the 121 fixed monitoring stations across the Nation, fall-out levels generally have decreased with distance from the test site. For example, radioactivity resulting from fall-out in the Northeastern States, has been only about one-tenth as great as that in Nevada and surrounding States.

### *Radiation Damage to Cattle*

Although beta particles cannot penetrate deeply, they may cause damage if a sufficient quantity of fall-out material is retained on or

5002071

near the skin for sufficient time. About 100 of a herd of 500 cattle suffered beta burns from fall-out following one of the 1952 tests. The cattle were grazing within the controlled area surrounding the proving ground. They suffered minor skin lesions which caused splotches of discolored hair, but neither their health nor their reproductive ability was impaired.

## Maximum Permissible Levels for Internal Radiation

Radioactive materials may be inhaled or taken into the body in food and water. It has been noted that minute amounts of radioactivity occur naturally in the tissues of plants, animals, and human beings. Above certain concentrations, however, radioactivity in the body is dangerous.

Evaluation of the health hazard from internal radiation involves several factors which need not be taken into account in the case of radiation from an external source. For example, alpha and low-energy beta particles emanating from radioisotopes outside the body are not significant external radiation hazards, since they cannot penetrate the skin. When these radiations originate from radioisotopes which have been taken into the body, however, they may damage tissues.

Some radioisotopes are eliminated from the body rapidly, while others concentrate in one or another body organ. For example, radium, calcium and strontium are concentrated primarily in the skeleton; cesium in the muscles, and iodine in the thyroid gland. Some organs are more sensitive to radiation than others. Concentration in the bones is of particular importance, since the period of retention is long and the vital blood-forming tissues in the skeleton are sensitive to radiation.

The maximum permissible concentrations of a radioisotope which concentrates in organs or tissues other than the skeleton generally is defined as the amount which will deliver a dose of 300 millirems per week to the organ in which the isotope is concentrated.

The maximum permissible concentrations of radioisotopes which are concentrated in the skeleton generally are determined by comparison with radium. The effects of radium are well-known, since hundreds of persons carry appreciable concentrations of radium in their skeletons as a result of accidental intake or therapeutic administration by physicians. Studies of persons who have carried radium in their skeletons for many years have shown that quantities as large as 1 microgram (one-millionth of 1 gram) produce no observable damage. To provide a safety factor, 0.1 microgram has been established as the maximum permissible body content of radium.

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Using the maximum permissible body content of radium as a standard, maximum permissible concentrations of other bone-seeking radioisotopes may be determined through comparing their effects with the effects of radium.

Fall-out material includes a number of radioisotopes, some of which are of more concern than others as internal radiation hazards. A maximum permissible air concentration for mixed fission products following a nuclear detonation has been established by the United States Atomic Energy Commission upon the recommendation of an advisory panel of experts. This concentration is 100 microcuries per cubic meter of air, averaged over a 24-hour period. Since particles between ½ micron and 5 microns are most likely to be retained in the lung, the maximum permissible concentration is 1 microcurie per cubic meter of air if the radioactivity is associated with particles less than 5 microns in diameter.

Safe concentrations of a mixture of fission products in drinking water depend upon the composition of the mixture and upon the period of time over which the water is used. It is estimated that water containing total fission product activity amounting to 0.005 microcurie per milliliter 3 days after the fission products were formed could be used safely for any period of time. To determine whether radioactivity measured in water at any other time after fall-out is safe, the measurement may be extrapolated to 3 days after formation and compared to the safe concentration noted above. If the water were to be used for only a few days or weeks, the concentration could be much higher without hazard.

## Fall-Out As a Source of Internal Radiation

### *Fall-Out Radioactivity in Air*

The highest concentration of airborne fall-out radioactivity observed within the 200-mile zone during the spring 1952 tests was 0.19 microcuries per cubic meter, averaged over a 24-hour period. The median diameter of this dust was approximately 2 microns, which is in the size range most likely to be retained in the lung. However, the concentration is less than a fifth of the maximum permissible concentration of 1 microcurie per cubic meter for dust of this size. It is estimated that the lungs would receive a total dose of about 200 millirem from this concentration of airborne radioactivity. This is approximately equal to the dose normally received by the lungs in 20 days from normal background radioactivity in the air.

Monitoring of airborne fall-out particles has shown that radioactivity is likely to remain significantly above background levels only

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for about a day. The levels noted above, therefore, quickly decrease to background levels.

The following table shows the highest airborne concentrations measured outside of the 200-mile zone. The highest concentration is between two- and three-hundredths of the maximum permissible level for dust in the size range most likely to be retained in the lung.

AIRBORNE RADIOACTIVITY IN LOCATIONS AT WHICH MAXIMUM FALL-OUT WAS OBSERVED OUTSIDE THE 200-MILE ZONE

| *Detonation* | *Locality* | *24-hour average concentration (Microcuries per cubic meter* |
|---|---|---|
| May 7, 1952 | Ogden, Utah | 0. 020 |
| May 25, 1952 | Price, Utah | 0. 001 |
| June 1, 1952 | Elko, Nevada | 0. 024 |
| June 5, 1952 | Elko, Nevada | 0. 014 |

### *Fall-out Radioactivity in Water*

The number of uncovered water sources in the area surrounding the proving ground is small. Measurements of radioactivity in such lakes and streams as exist in the area have shown no levels approaching the maximum permissible level for water consumed over an indefinite period. The table below shows results of measurements made during the spring 1952 test series. (Several other samples, including water from Lake Mead and drinking water at Las Vegas, Pioche, and Camp Mercury, did not contain detectable radioactivity.)

WATER ANALYSIS FOR RADIOACTIVITY NEAR NEVADA TEST SITE

| *Date* | *Source* | *Approximate distance from ground zero (air miles)* | *Analysis (microcuries per milliliter at 3 days after detonation)* |
|---|---|---|---|
| May 1, 1952 | Crystal Springs Pond | 63 | 0. 5 x $10^{-8}$ microcuries |
| May 1, 1952 | Pahranagat Lake | 56 | 1. 0 x $10^{-8}$ microcuries |
| May 2, 1952 | Caliente—Drinking Water | 95 | 0. 28 x $10^{-8}$ microcuries |
| May 2, 1952 | Creek North of Caliente | 97 | 1. 1 x $10^{-8}$ microcuries |

*Fall-out in Water Supply Systems.* Various studies have been conducted under Commission sponsorship to determine the fate of fall-out material deposited in reservoirs and the ability of treatment plants to remove radioisotopes from water.

Harvard University has studied fall-out material in surface waters of Massachusetts and in reservoirs which supply water to the city of Boston. It has been found that the radioactive particles tend to settle

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to the reservoir bottom. Further studies will be carried out to determine whether the spring and autumn "turnover" of water in reservoirs (a common occurrence resulting from water temperature differentials) disturbs settled radioactive particles.

Radioactivity in samples of Merrimac River water from the Lawrence, Mass., water treatment plant was measured in another series of experiments conducted independently by the Massachusetts State Department of Health. It was found that the plant removed 84 percent of the observed radioactivity, the largest drop occurring in passage through the rapid sand filters.

Experiments at the Oak Ridge National Laboratory and at the Massachusetts Institute of Technology over a period of several years indicate that water treatment plants remove some radioisotopes more effectively than others. Certain conventional water treatment methods are relatively ineffective in removing strontium, but removal of this isotope can be increased substantially by using phosphate and lime in the treatment process.

Studies also have shown that fall-out radioactivity disappears more rapidly in surface waters than may be accounted for by nuclear decay alone. Evidently other factors, such as deposition, biological uptake and absorption, are involved. These factors will be given further study.

## Long-Term Effects of Fall-Out

In determining that nuclear tests could be held at the Nevada Proving Ground without serious hazard to the public, the Commission gave consideration to the possibility that hazardous levels of radioactivity might be built up as a result of a number of successive tests.

Because of the rapid decay of fission product activity, the fall-out residue from successive tests would be extremely unlikely to build up to levels which could be considered an external radiation hazard. The uptake of fission products by food and field crops is of greater potential concern, since these crops may be eaten by human beings or animals. Radioactive materials in plants, like those in air and water, are hazardous only when they are present in amounts which would produce concentrations in the body well above accepted maximum permissible concentrations.

Long-term effects of successive tests, both from the standpoint of external radiation and uptake by plants, are discussed in greater detail below.

*External Radiation.* Total radioactivity estimated to be remaining on January 1, 1953, in communities inside the 200-mile zone as a result of the eight detonations in the spring 1952 series is shown in the

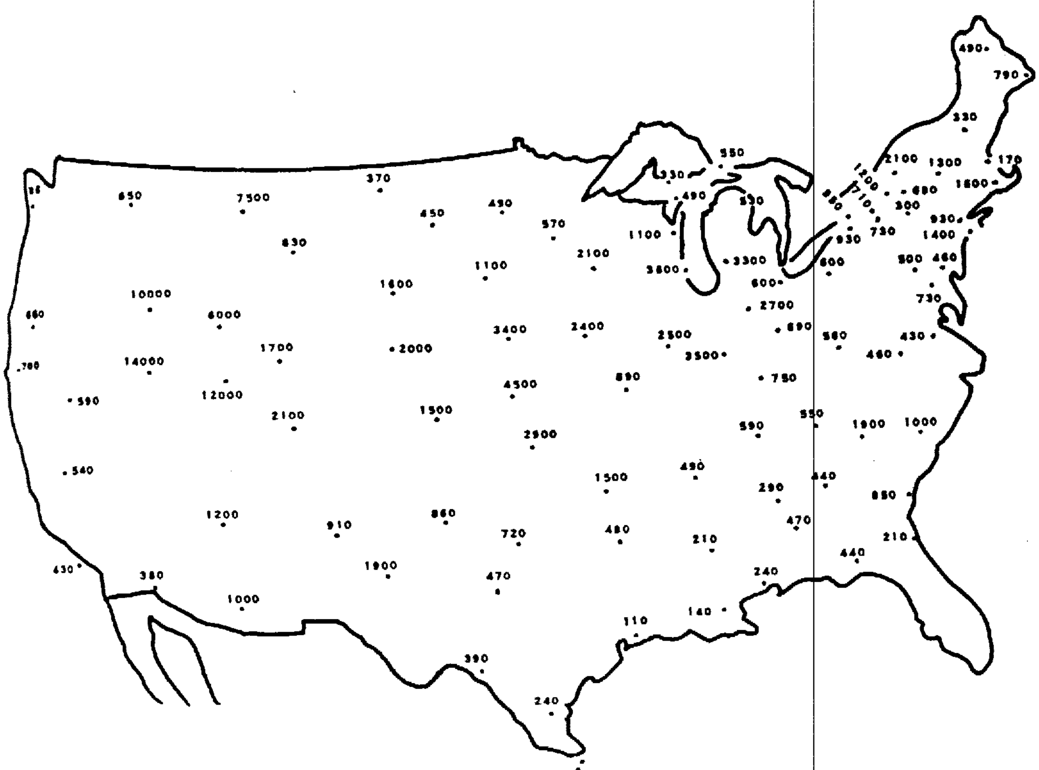
5002075

following table. The units used are disintegrations per minute per square foot for a sample collected over a period of 24 hours.

| Location: | $D/M/ft^2$ |
|---|---|
| Las Vegas | 21,000 |
| Crystal Springs | 5,400 |
| Alamo | 9,000 |
| Caliente | 8,300 |
| Beatty | 18,000 |
| Tonopah | 740 |
| Ely | 117,000 |
| Indian Springs | 44,000 |

The highest figure in the above table—that for the sample taken at Ely, Nev.—represents gamma exposure estimated to be less than that resulting from normal background radiation.[12]

Radioactivity remaining on January 1, 1953, in other parts of the Nation as a result of the Spring 1952 test series is shown on the accompanying map. The map shows residual activity varying from 100 to 14,000 disintegrations per minute per square foot, depending on location. Exposure resulting from such levels of radioactivity would be far less than that received from normal background. It is apparent that the radioactivity resulting from the spring 1952 test



[12] The data in this table, as on the map on this page, are valuable in estimating the relative distribution of fall-out and in assessing the long-term effects of radioactive materials in the soil. These figures, however, represent beta counts, which cannot be converted into terms of external gamma exposure with a good assurance of reliability. The rough estimates which are possible, however, indicate that none of the activities shown in the table would result in gamma exposure greater than the normal background.

series has decayed to levels which have no significance as a source of external radiation.

*Soil Radioactivity.* The radioactivity remaining in the soil in Nevada and surrounding states as a result of the three test series held to date is indicated on the chart on page 121. As the chart shows, the activity rapidly decays to levels considerably below the natural radioactivity present in the top 12 inches of the ground.

The unbroken curve at the left of the chart shows the increase in radioactivity in the soil resulting from the spring 1951 tests. Some activity from these tests still remained in the soil when the next series of tests was begun in the fall of 1951. The unbroken curve in the middle of the chart, therefore, represents both this activity and the new activity added by the fall tests. The unbroken curve at the right shows the total activity resulting from the spring 1951, fall 1951 and spring 1952 tests. The broken curve shows the total strontium activity resulting from the three series.

The mixture of radioactive materials in fall-out differs from that of the radioisotopes which occur naturally in the soil. The proportion of plant uptake also differs, as does the biological importance of the materials taken up by plants. Therefore, comparison of the fall-out curves on the chart with the level of natural soil radioactivity cannot be considered a direct comparison of the relative hazards involved in plant uptake. However, experimental growth of plants in soil containing thousands of times the residual fission product activity represented by the curves on the chart has indicated that there is no hazard from residual activity outside of the Proving Ground. These experiments are described below.

*Plant Experiments.* Plants have been grown in soil containing a concentration of fission products equivalent to that produced by the maximum fall-out observed in the immediate vicinity of the point of detonation. Radishes, barley, oats, cowpeas, and ryegrass were used in these experiments. The principal fission product taken up by the plants was radioactive strontium. Experiments with soils of varying calcium content showed that the strontium uptake is much less for soils rich in calcium.

One to two hundred pounds of these plants, grown in the very high concentrations of fission products which might be found in the immediate vicinity of the detonations on the proving ground, could be eaten by an individual without acquiring the maximum permissible body burden of radioactive strontium. The maximum radioactive content of plants grown at a distance of a few miles from the point of detonation would be considerably lower.

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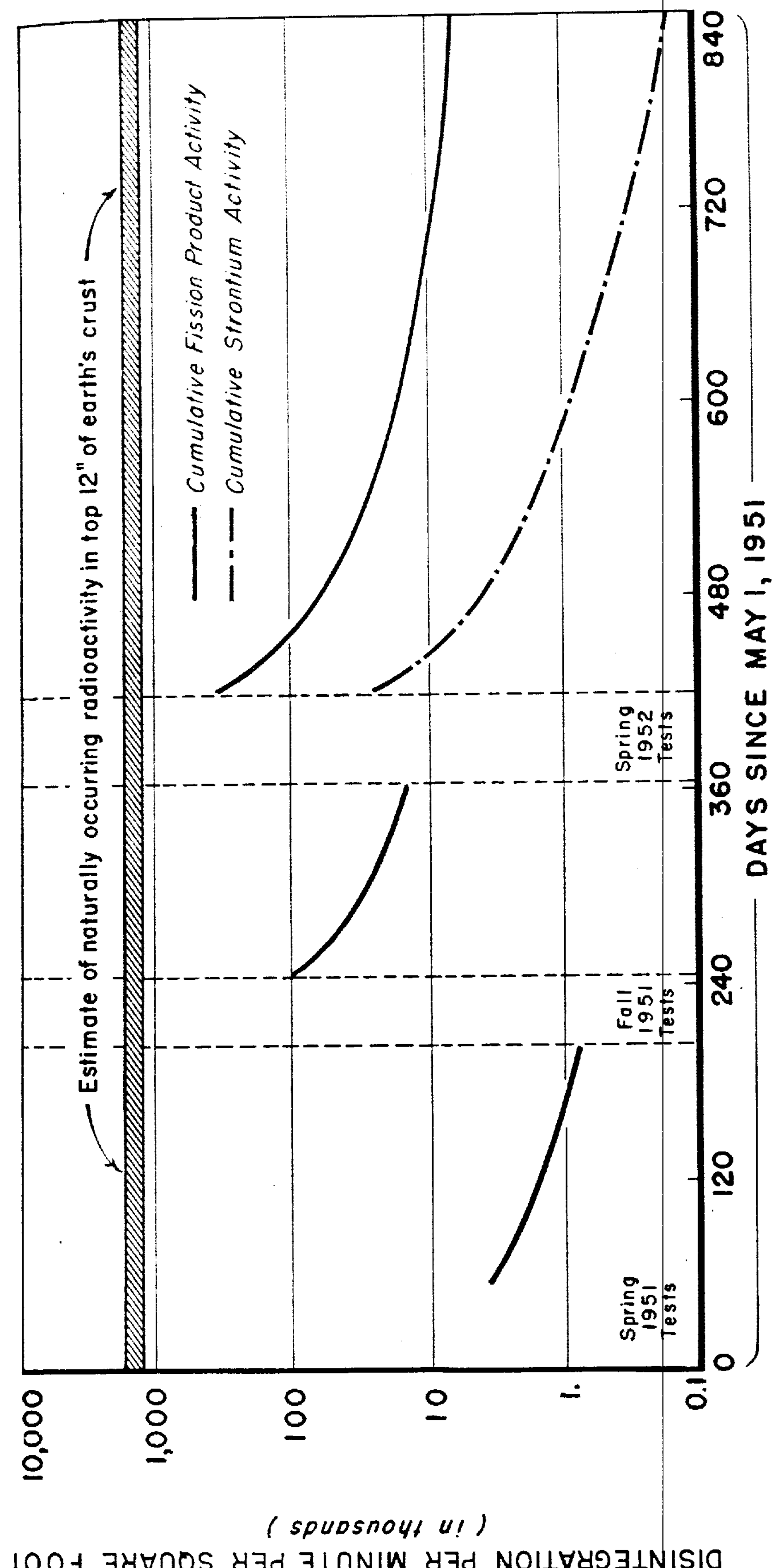
FALL-OUT RESIDUE, NEVADA AND SURROUNDING STATES



*Uptake by Animals.* Cattle and other animals may eat plants which contain radioactive materials from fall-out. Studies have been made of the possibility of hazard to humans as a result of eating meat from such animals. These studies indicate that the bone-seeking radioisotopes are of greatest potential concern, and that the chief among these is radiostrontium.

Cattle absorb 25 to 30 percent of the ingested strontium, with about 25 percent reaching the bone. A few days after entrance of radiostrontium into the body, about 99 percent of the remaining amount will be in the bones. The only potential hazard to human beings would be the ingestion of bone splinters which might be intermingled with muscle tissue during butchering and cutting of the meat. An insignificant amount would enter the human body in this fashion.

Fission products distributed in water may be accumulated by aquatic animals and plants. Here again, data gathered at Bikini and Eniwetok as well as in this country indicates that there is no radiation hazard to human beings from this source.

The amount of fall-out radioactivity in water decreases rapidly because of radioactive decay and dilution by water from outside the fall-out area. The rate of decrease is illustrated by the amount of radioactivity in fish in the lagoon at Eniwetok. The average radioactivity of the various fish caught was relatively high on the day following a detonation, although it did not reach dangerous levels. Two months later, the radioactivity in fish in the lagoon had decreased to a fraction of 1 percent of the initial amount.

The amount of radioactivity accumulated by water life also decreases rapidly with distance from a detonation. Fish caught in areas 7 to 14 miles distant from the test site 2 months after tests at Eniwetok had an average radioactivity amounting to only 5 percent of that in fish caught near the site.

## Genetic Effects of Radiation

The preceding sections of this report have dealt with the somatic effects of radiation; that is, bodily changes which are not inherited, but which disappear with the death of the individual. However, radiation also can affect the germ cells in animals and plants and thus affect the characteristics passed on from one generation to the next.

Mutations, or changes in the units of heredity in the germ cells which eventually may appear as new or different characteristics in offspring, occur spontaneously under natural conditions in all kinds of animals and plants. Background radiation is one factor in the natural mutation rate, but apparently it is a minor one.

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It is important to recognize that radiation does not cause any mutations which are not produced naturally in other ways. Radiation, however, increases the frequency of mutations above the normal rate, and the increase seems to be in direct proportion to the dosage. Since most mutations are disadvantageous, large increases are considered undesirable.

We have noted that low levels of radiation produce no detectable somatic effect; that is, the body is able to repair the damage virtually as quickly as it occurs. Such low-level exposure can be continued indefinitely without any detectable bodily change. This does not seem to be the case for the germ plasm. Evidence accumulated to date indicates that mutations are in proportion to the dose, with no repair or recovery process at work. It follows that small doses are cumulative in their genetic effects, and that daily or weekly repetitions of such doses over a long period could produce a noticeable increase in the numbers of mutations among offspring.

Studies have been made of the increase in the mutation rate among mice as a result of exposure to radiation. If these data can be applied to human germ cells, it may be calculated that the natural rate of human mutation would be doubled by exposing the germ cells to about 80 roentgens. This is 1,600 times higher than the lifetime exposure level of 50 milliroentgens noted in communities surrounding the test site as a result of fall-out. It is 35 times more than the lifetime exposure which would result from the highest fall-out radioactivity noted outside the test site itself—the reading taken at one of the nearby mines.

The natural human mutation rate is so low that it is doubtful that a doubling would be noticeable in one generation since a large proportion of the mutations are recessive. Data collected by the Atomic Bomb Casualty Commission in Japan indicate an insignificant increase in the number of detectable mutations in the children of persons subjected to radiation hundreds or thousands of times greater than that from fall-out. On the basis of experiments and observations so far made, it appears that over a number of generations radiation from fall-out from Nevada tests would have no greater effect on the human mutation rate in the United States than would natural radiation in those parts of the Nation where the background levels are high.

## Future Monitoring and Research Programs

Although the precautions taken to prevent hazard to the public from continental weapons tests have proved to be adequate, there is a continuing need for monitoring levels of fall-out radioactivity. The

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monitoring program will be continued in connection with future tests at the Nevada Proving Ground for the following reasons:

(a) Monitoring of future tests will provide a continuing record of residual soil radioactivity from fall-out. This record will give ample warning of any possibility of a dangerous accumulation of radioactivity at any future time as a result of numerous successive tests.

(b) Monitoring of future tests should provide additional information regarding the relation of fall-out to weather conditions and to the type of burst. Such information will be of use in making even more precise the protection of the public.

(c) Monitoring in communities near the Nevada Proving Ground will assure that proper precautions are taken by residents should fall-out radiation ever reach the maximum permissible level.

(d) Monitoring will continue to provide guidance to industries affected by slight increases above the normal background radiation level.

Various research projects relating to fall-out also should provide valuable information in the future. These studies include further research into uptake of various radioisotopes by food and field crops and into methods of removing radioistopes from water supply systems. Various studies of the effect of radiation on the human body also should provide data of use in evaluating possible effects of fall-out.

## Conclusion

It has become evident from the studies on fall-out from the clouds produced by 20 explosions of atomic bombs at the Nevada Proving Ground that these explosions created no immediate nor long range hazard to human health because of fall-out outside the proving ground. The studies have shown:

(a) *As to external exposure due to gamma radiation from fall-out material.* The greatest exposure measured at any inhabited point was below the maximum permissible exposure, with only a few towns and cities showing even an appreciable fraction of this value.

(b) *As to radioactivity in the air following any of the 20 shots.* The maximum concentration measured at any inhabited locality was about one-fifth as great as the maximum permissible concentration, and this activity remained in the air for less than 24 hours.

(c) *As to radioactivity present in water sources near the proving ground.* The maximum at any location was several thousand

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times below the amount that could be safely consumed for an indefinite period.

(d) *As to the taking up of radioactivity by plants.* The maximum taken up in experiments with plants grown on soils containing several thousand times the radioactivity that was occasioned by fall-out off the proving ground was so small that a human being would have to eat 200 pounds of the plant material to reach a maximum permissible concentration in the body.

(e) *As to the taking in of radioactivity by animals eating plants grown in soil affected by the fall-out from the tests.* Experiments have indicated that there is no hazard to human health from this source.

(f) *As to possible changes in mutation rate of humans exposed to radioactivity from fall-out.* It would take 1,600 times the average radioactivity deposited by fall-out in communities surrounding the proving ground and 35 times the highest radioactivity deposited from fall-out to bring about a doubling of the number of mutations occurring naturally in human beings from one generation to another.

To sum up, the experience with 20 experiments with atomic devices at the Nevada Proving Ground has been that there is negligible hazard to property from blast; that proper warnings and patrolling have prevented any injury to humans from heat, light, or blast; and that the highest levels of radioactivity released by fall-out of particles are well below the very conservative standards fixing the amounts of radiation that can be received externally or internally by the human body without harming the present or later generations.

The AEC is continuing to refine and strengthen the system of warning, monitoring, and reporting. The agency is now making arrangements with public health officers of local Governmental units so that they may be kept apprised of the levels of radioactivity resulting from fall-out from the explosion clouds. It is the Commission's hope that in the near future there will be no occasion for alarm through lack of knowledge of the facts about levels of radiation and their degree of hazard, just as there is now no reason in actuality for alarm, since the radioactivity released by fall-out has proved not to be hazardous.

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